

# **PITFALLS OF SPECTRAL REDUCTIONS AND THE CALIBRATION PROCESS**

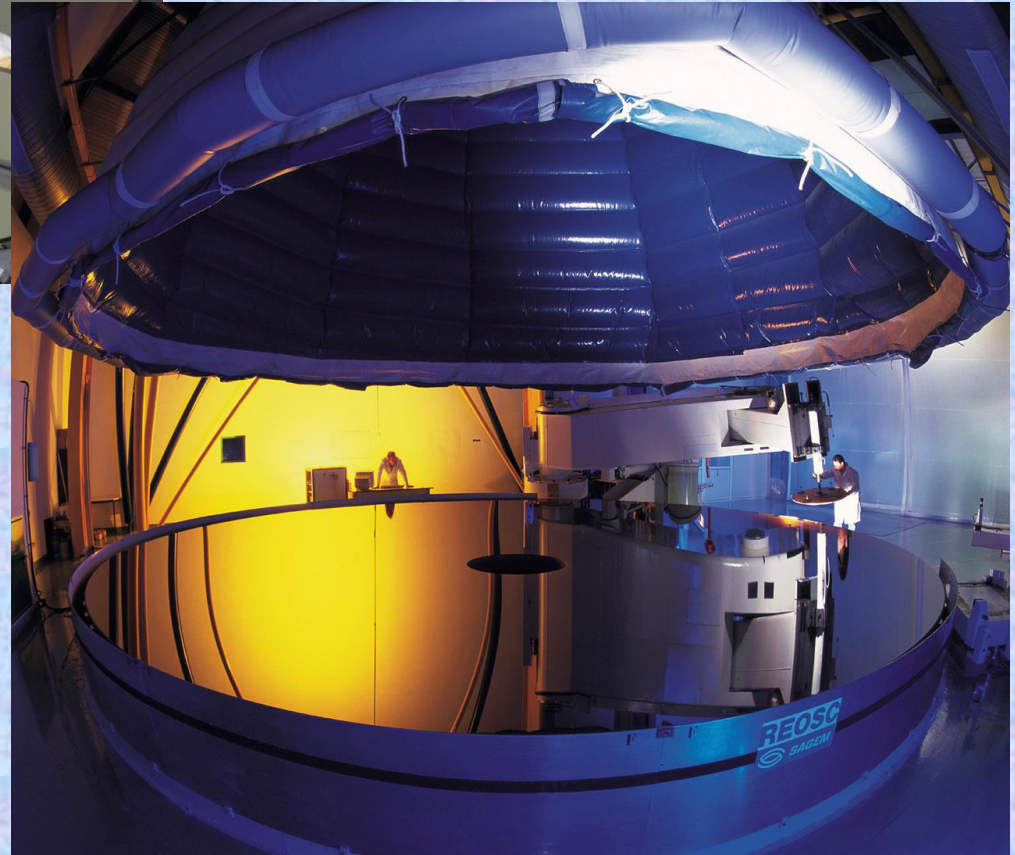
Jan Janík

Spectroscopic workshop, 6.-10.2.2017, Brno

A close-up photograph of numerous lit candles, creating a warm, glowing atmosphere. The candles are of various heights and are densely packed, with their flames flickering and casting a soft, golden light. The background is dark, making the light from the candles stand out prominently. Overlaid on the center of the image is the text "WE NEED MORE LIGHT !!!" in a bold, black, sans-serif font.

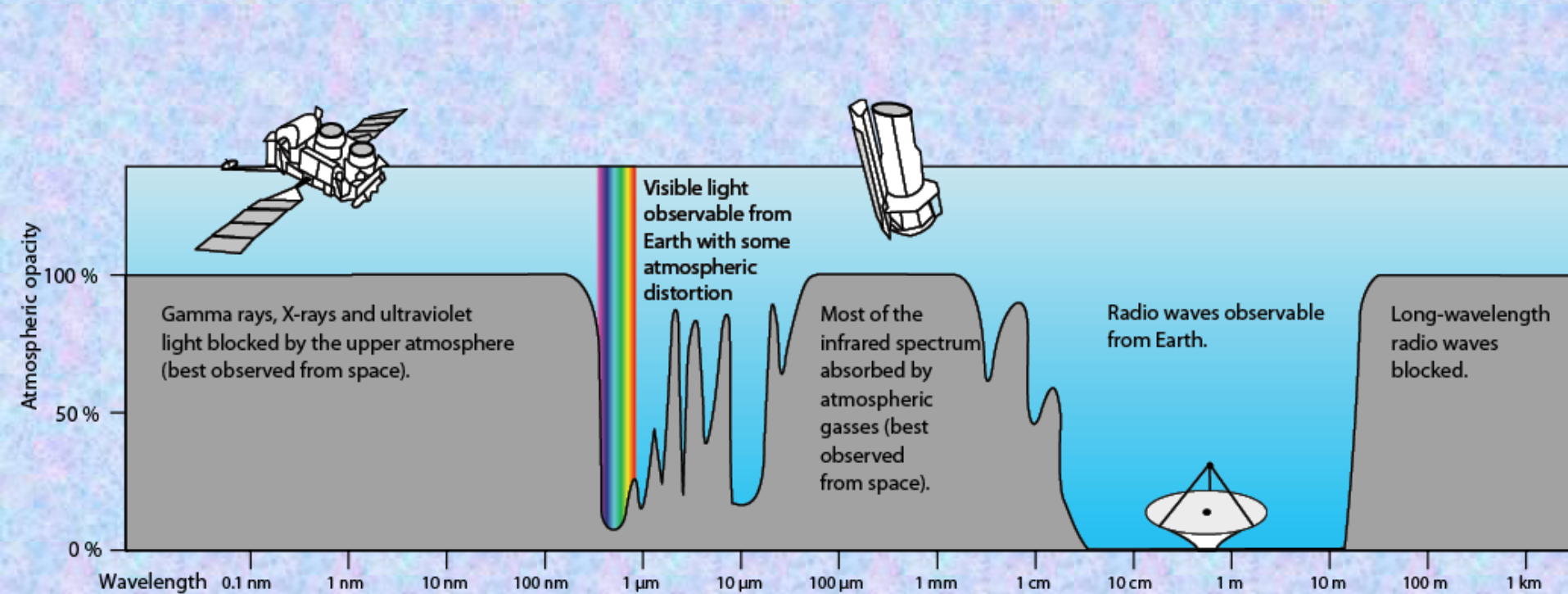
**WE NEED MORE LIGHT !!!**

# BIGGER TELESCOPES

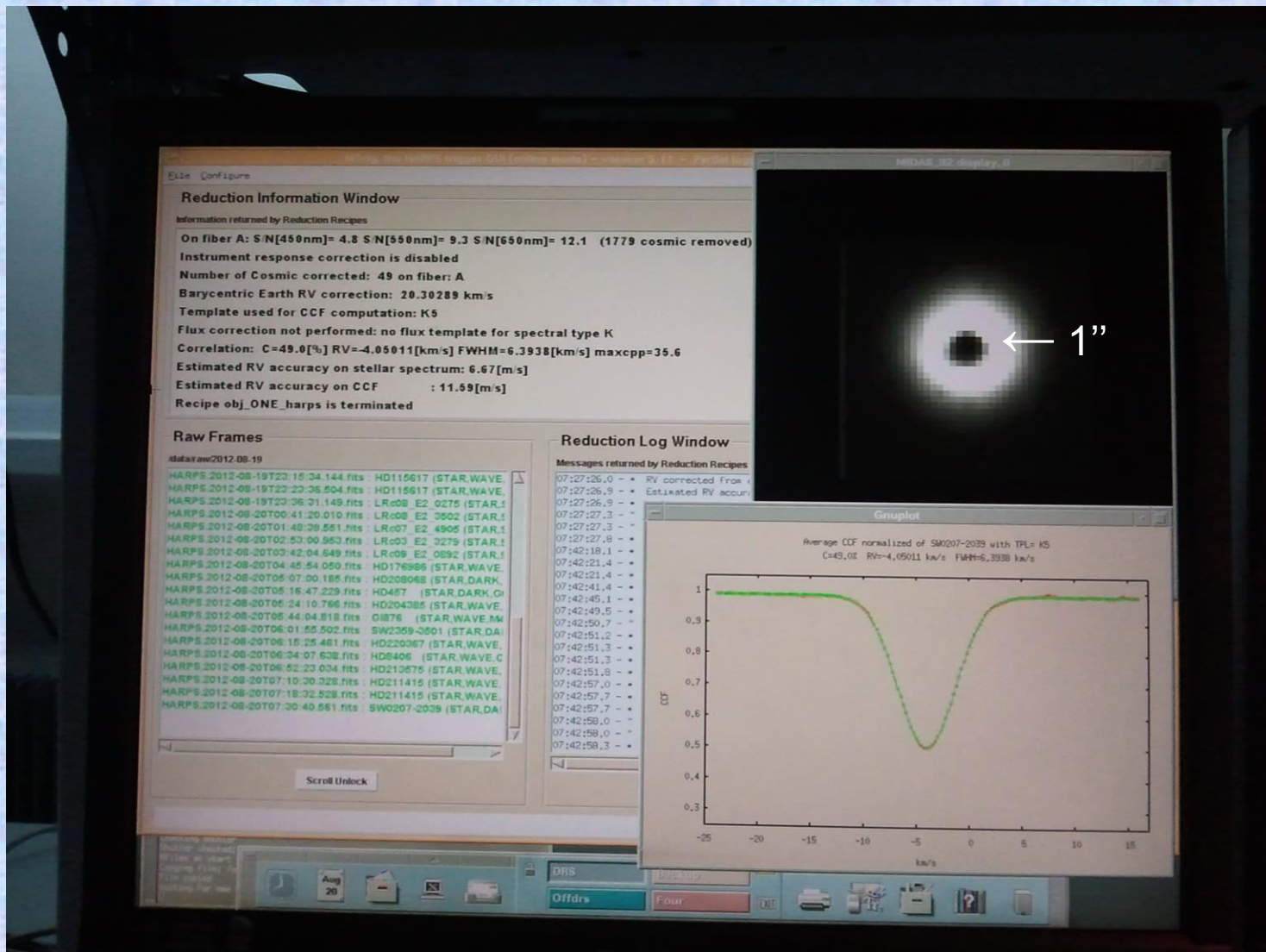




# ATMOSPHERE - FILTER

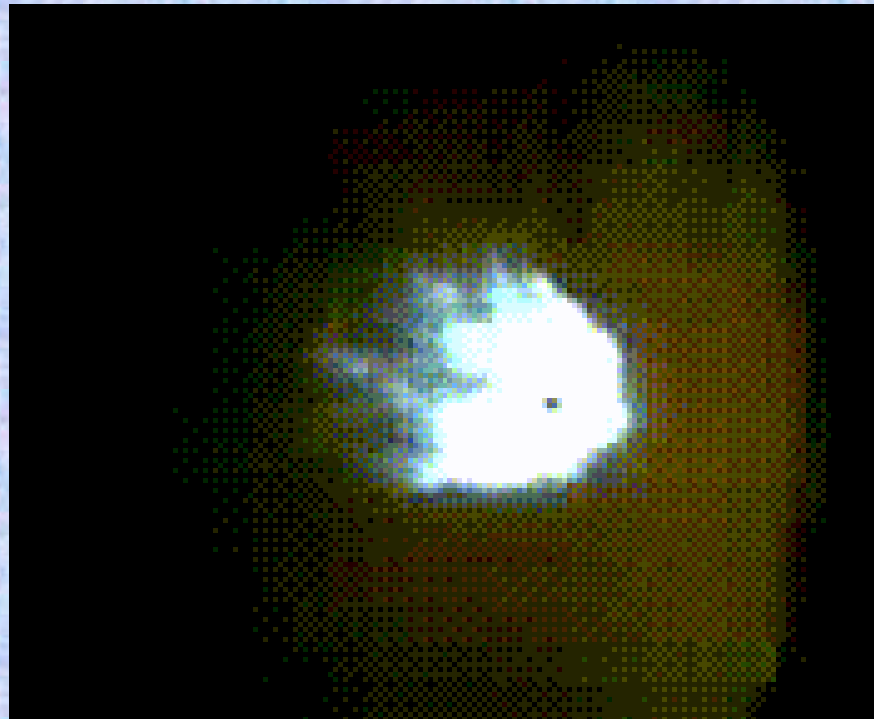


# ATMOSPHERE - SEEING



# ATMOSPHERE - SEEING

- Big seeing – smaller than 10 % of light to spectroscop

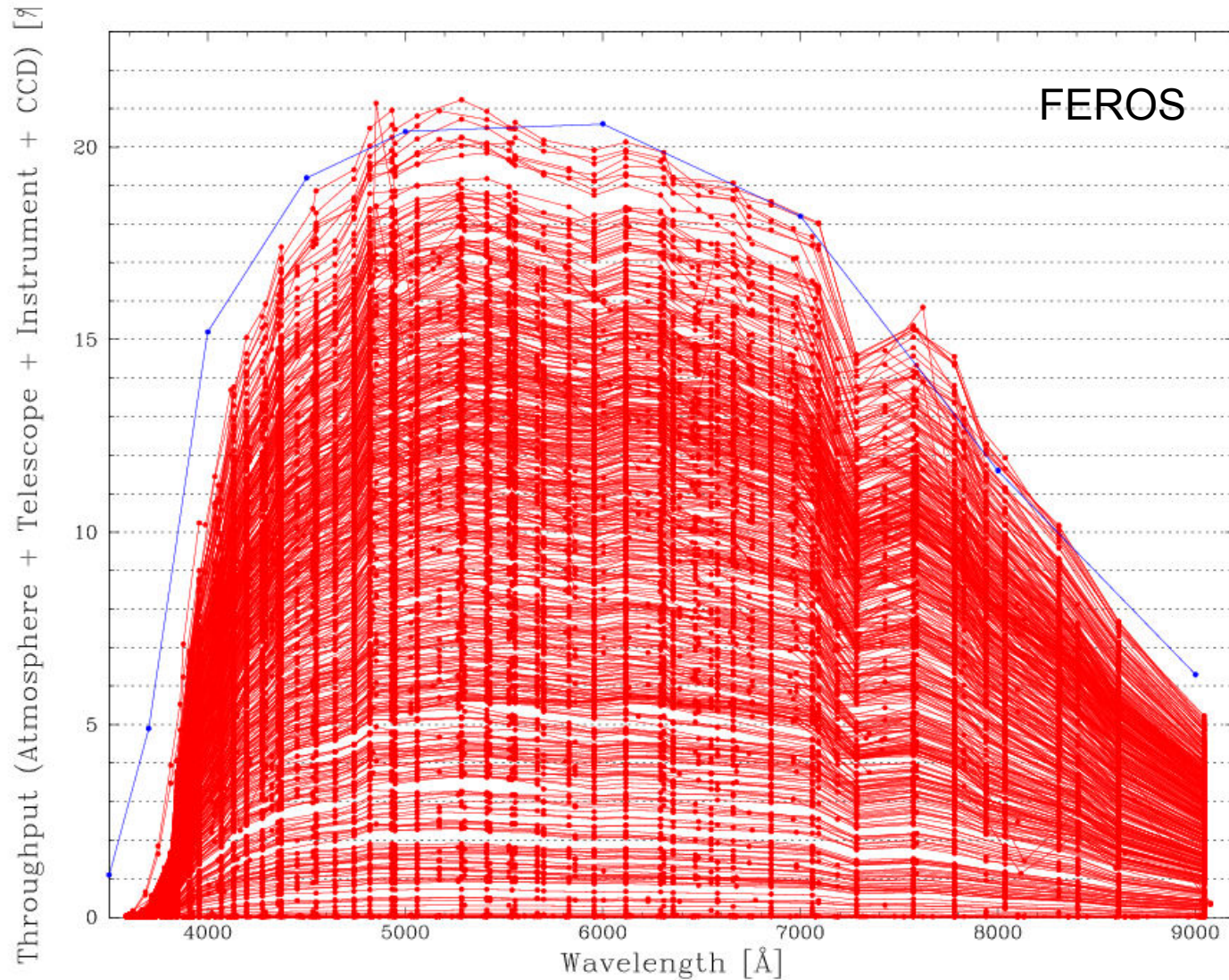


# ATMOSPHERE – AdO+AcO



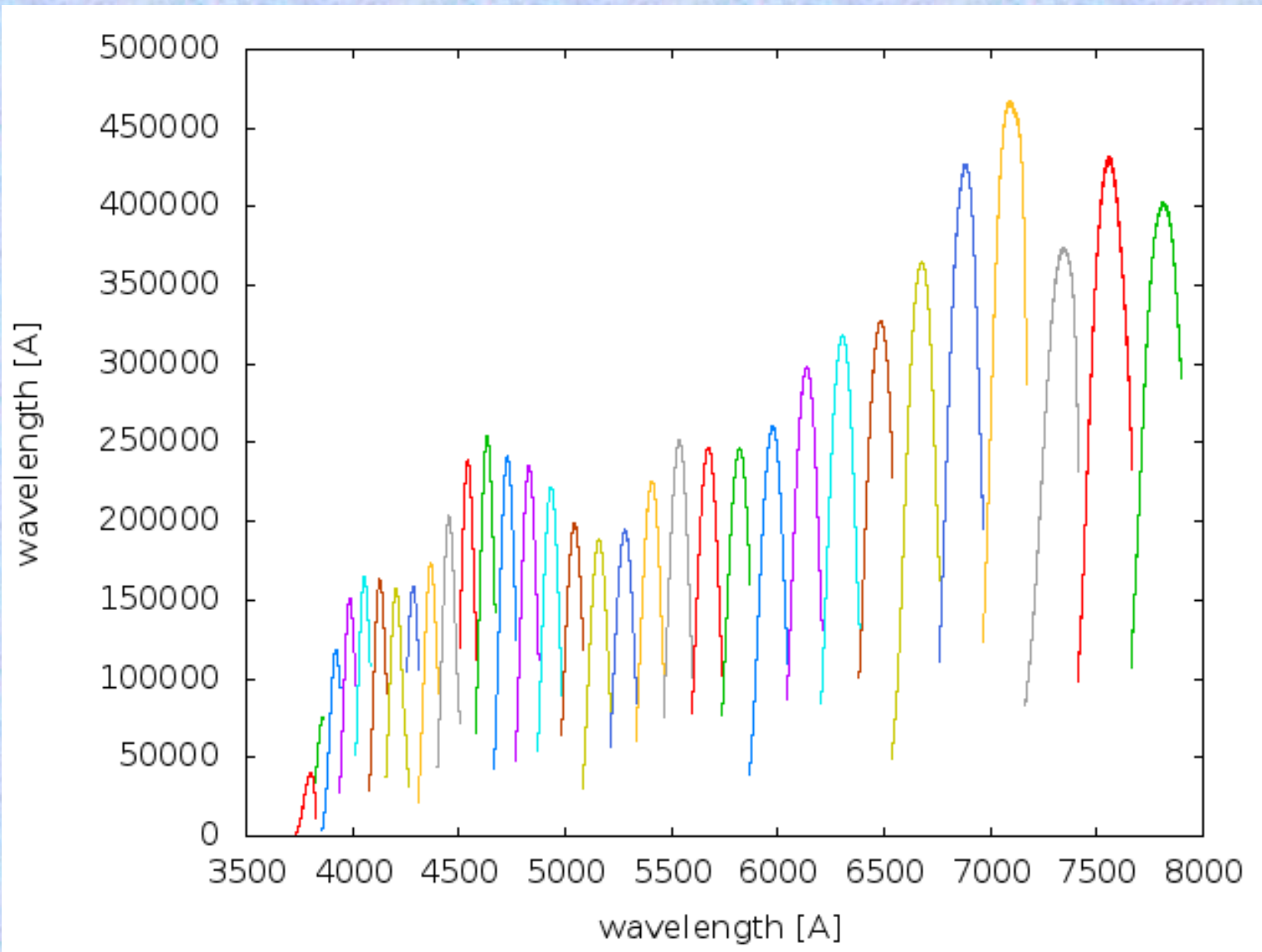


# SPECTROSCOP EFFICIENCY



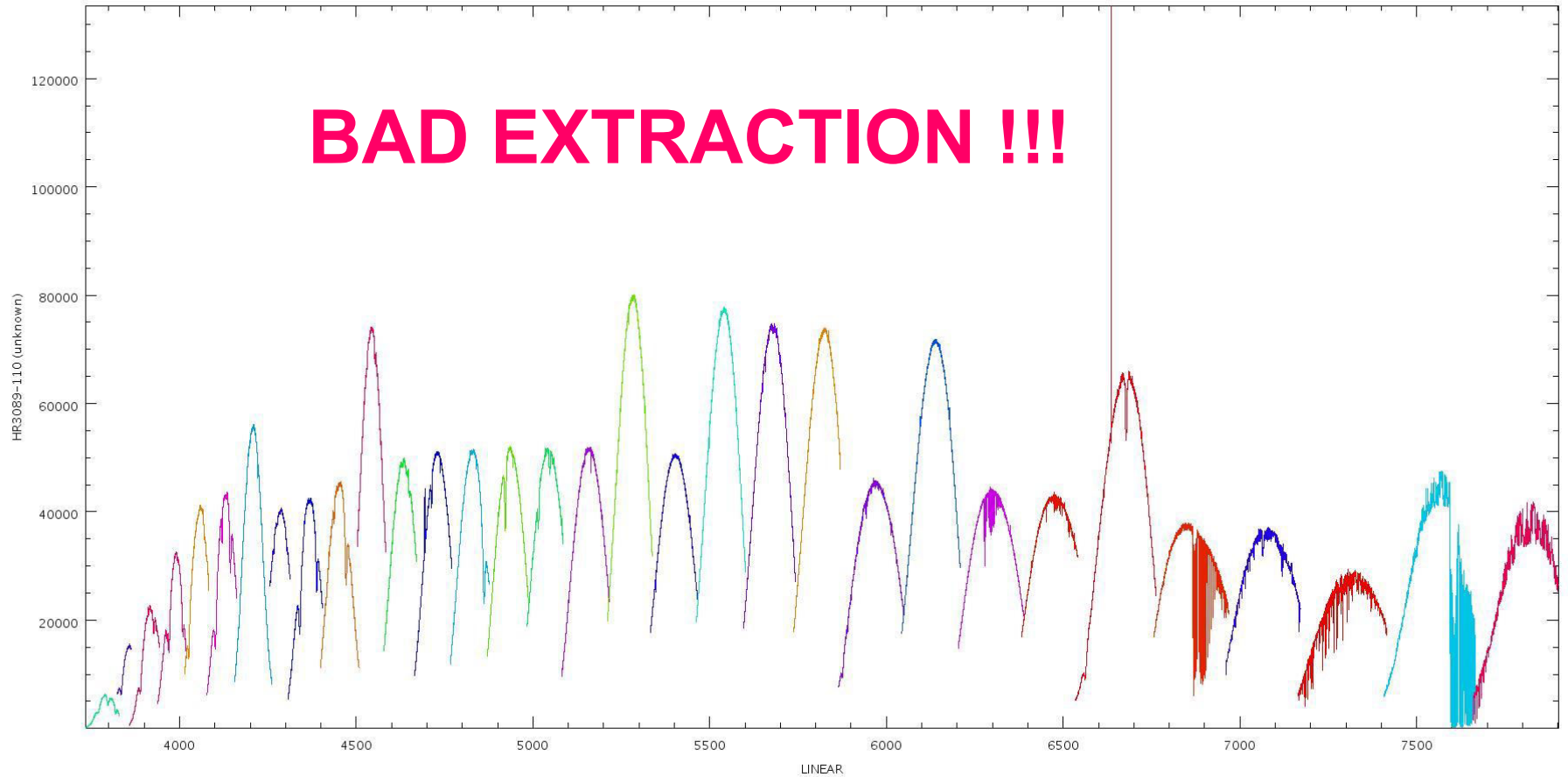


# APERTURE DEFINITION



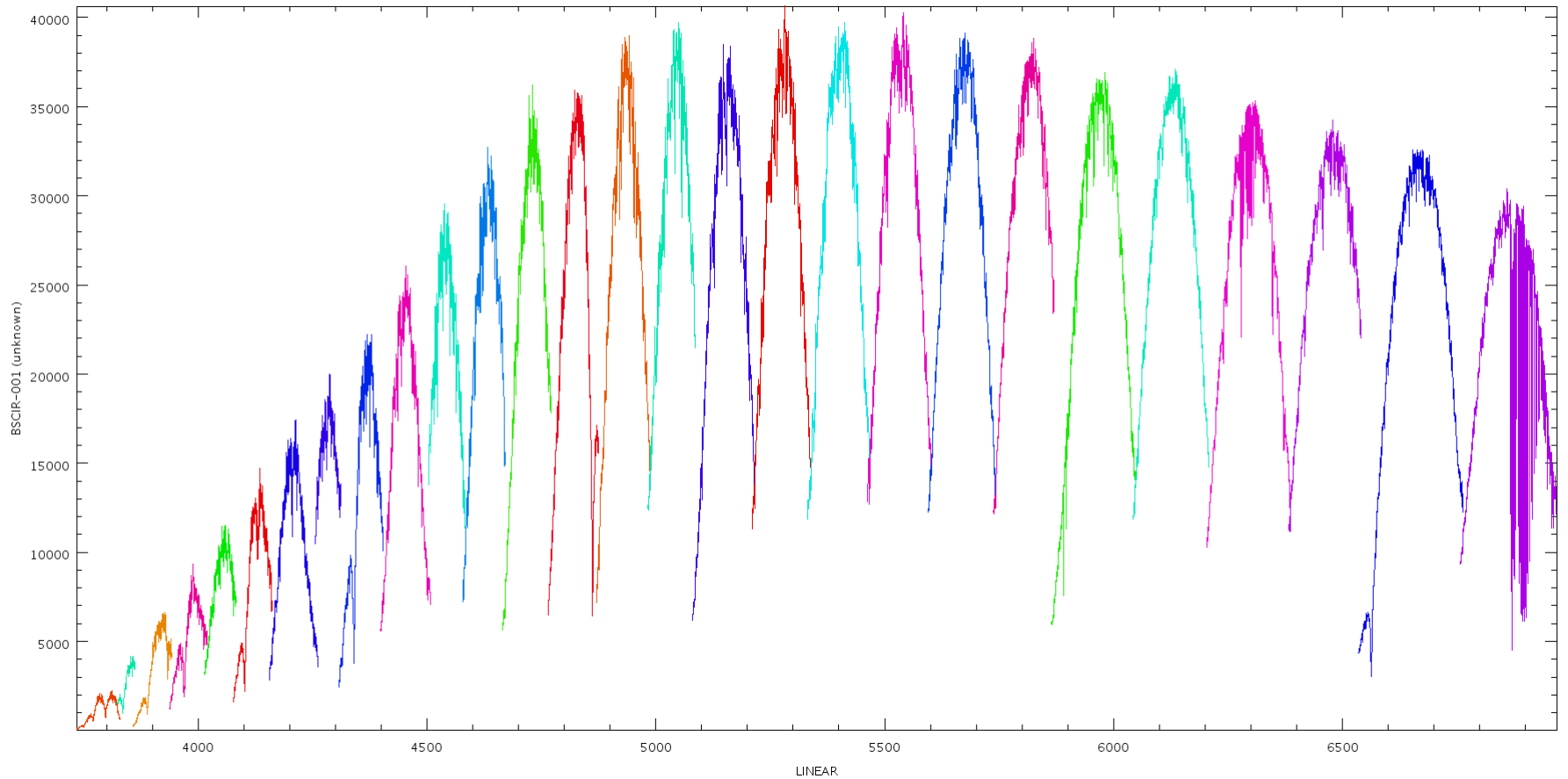
# APERTURE DEFINITION

2-d compound coordinate system



# APERTURE DEFINITION

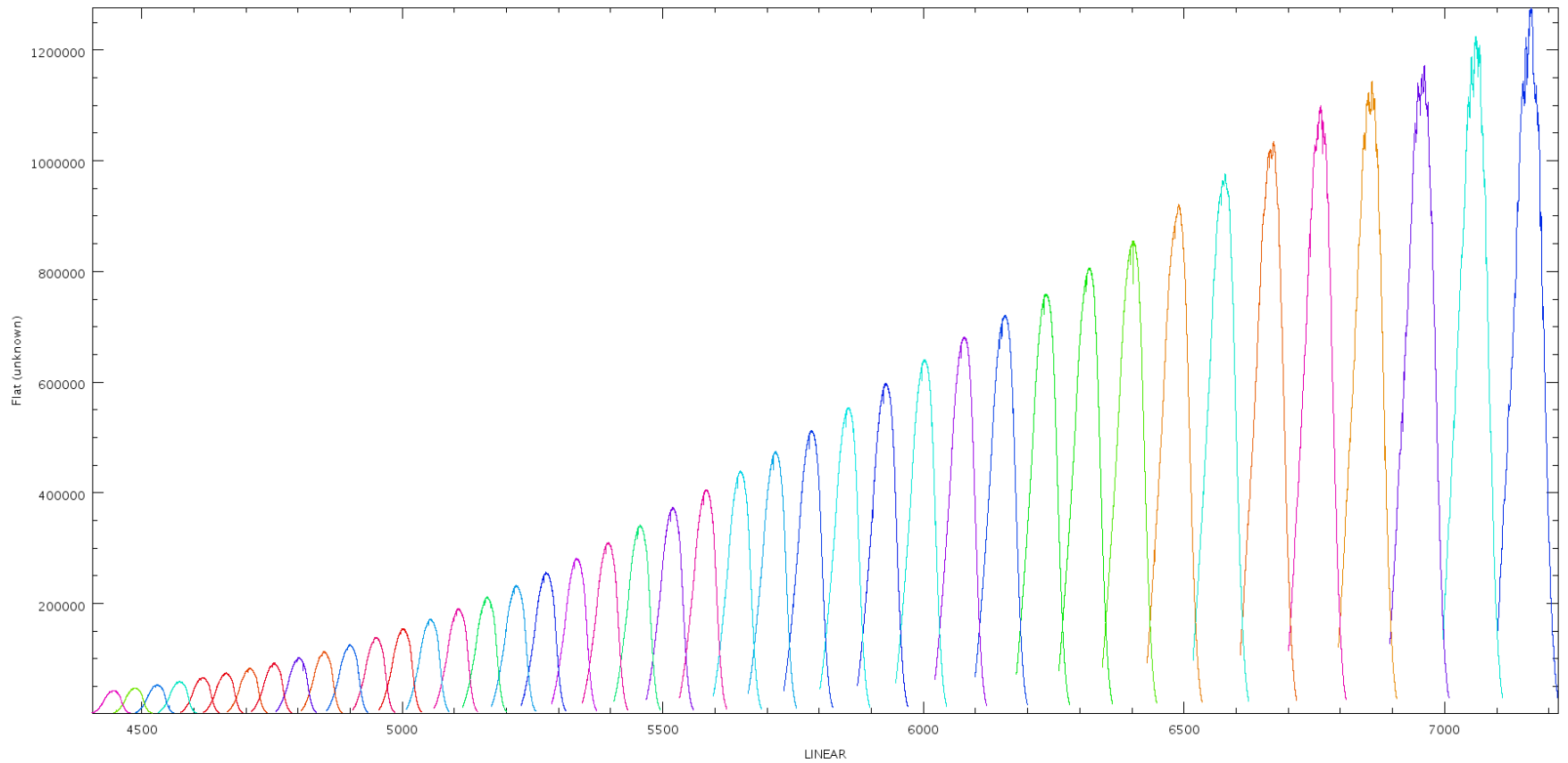
2-d compound coordinate system





# APERTURE DEFINITION

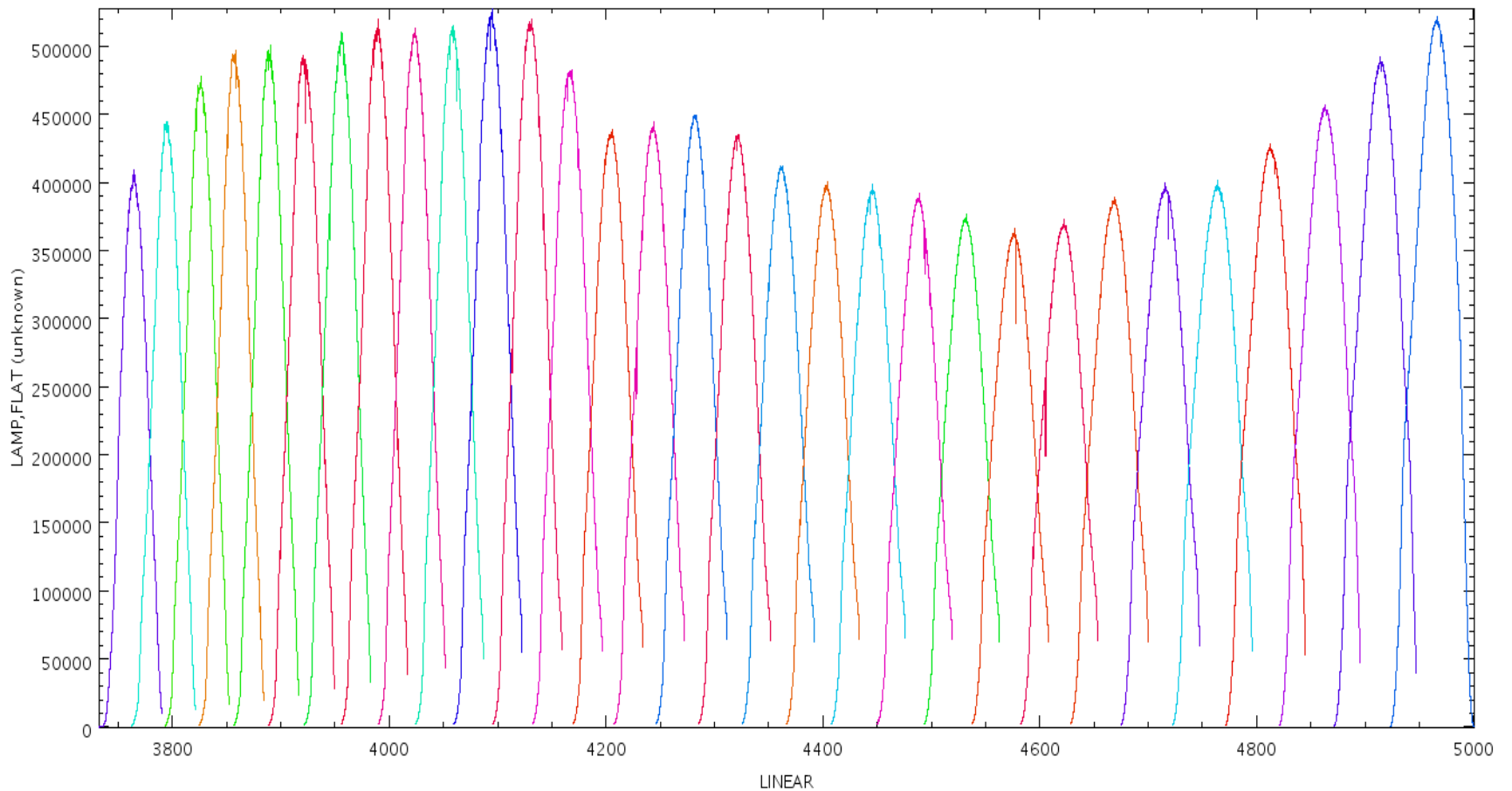
2-d compound coordinate system



# APERTURE DEFINITION

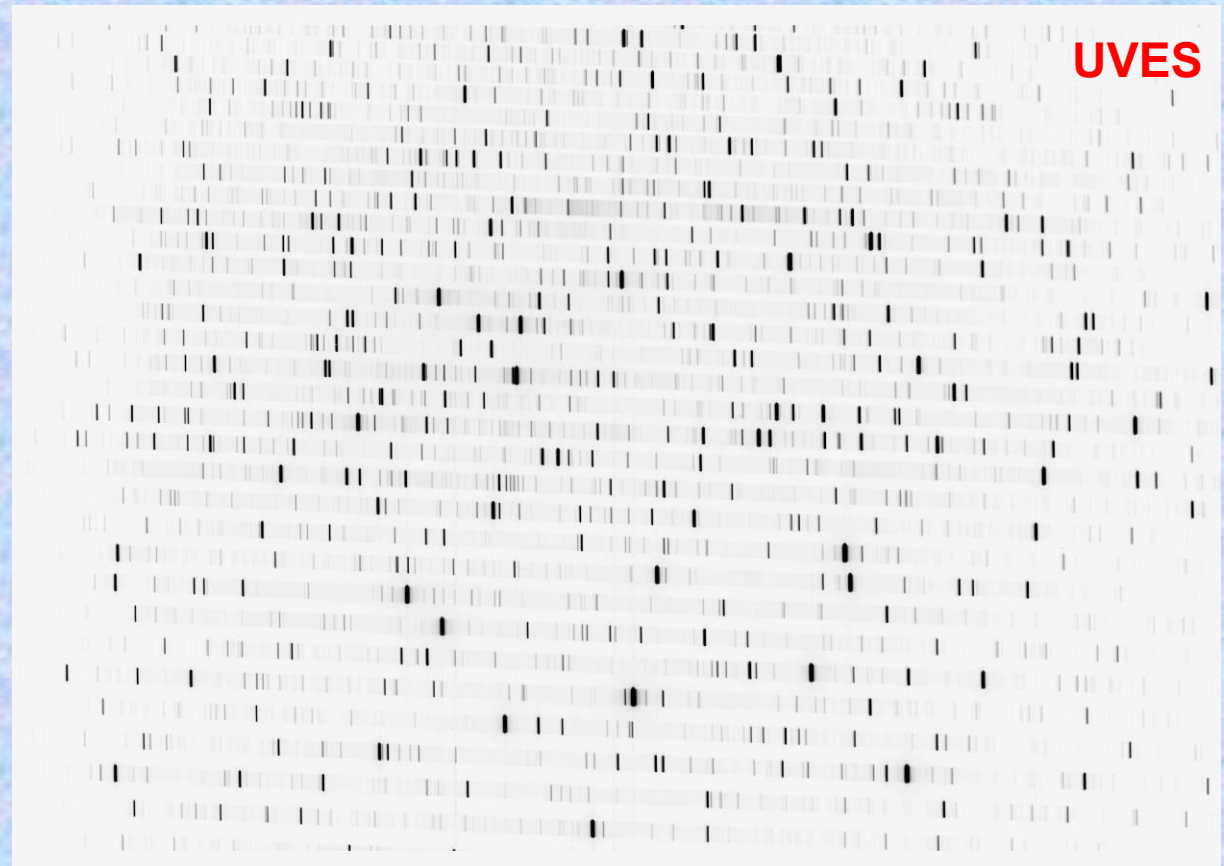
**UVES**

2-d compound coordinate system



# WAVELENGTH CALIBRATION

- Th-Ar
- Th-Ar-Ne
- Iodine cell

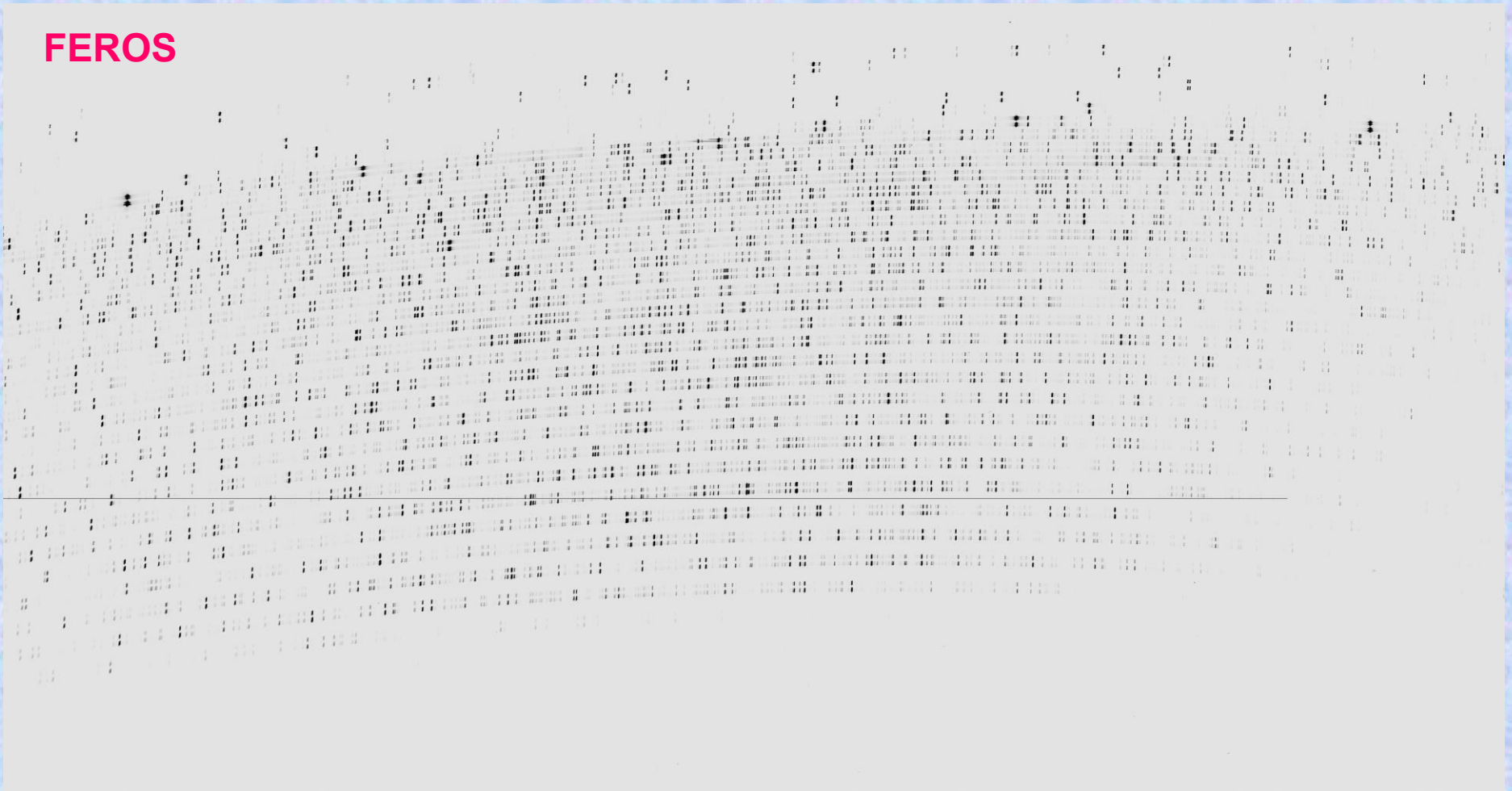


- The best precision for RV as possible !!!



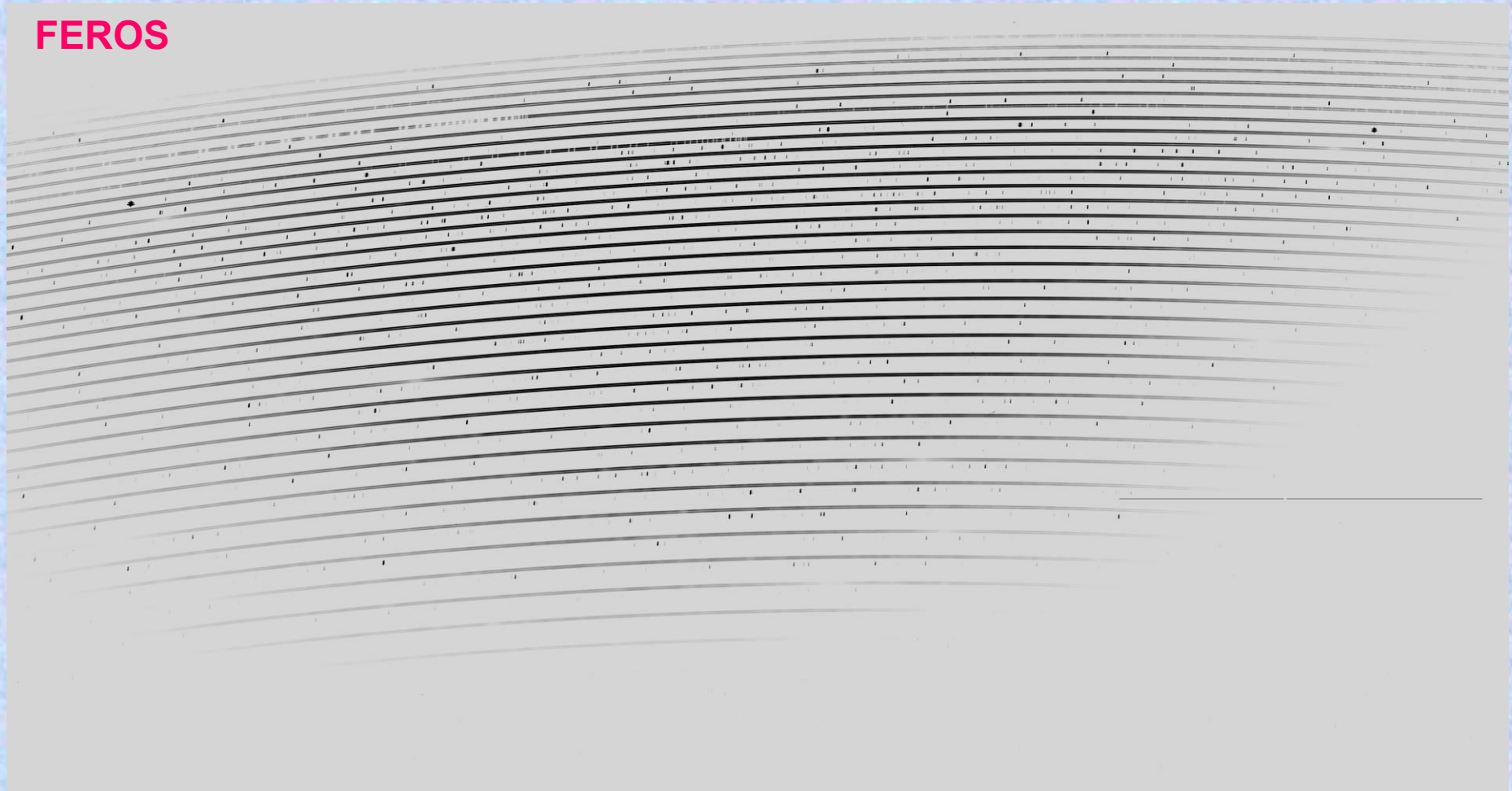
# WAVELENGTH CALIBRATION

FEROS



# WAVELENGTH CALIBRATION

FEROS

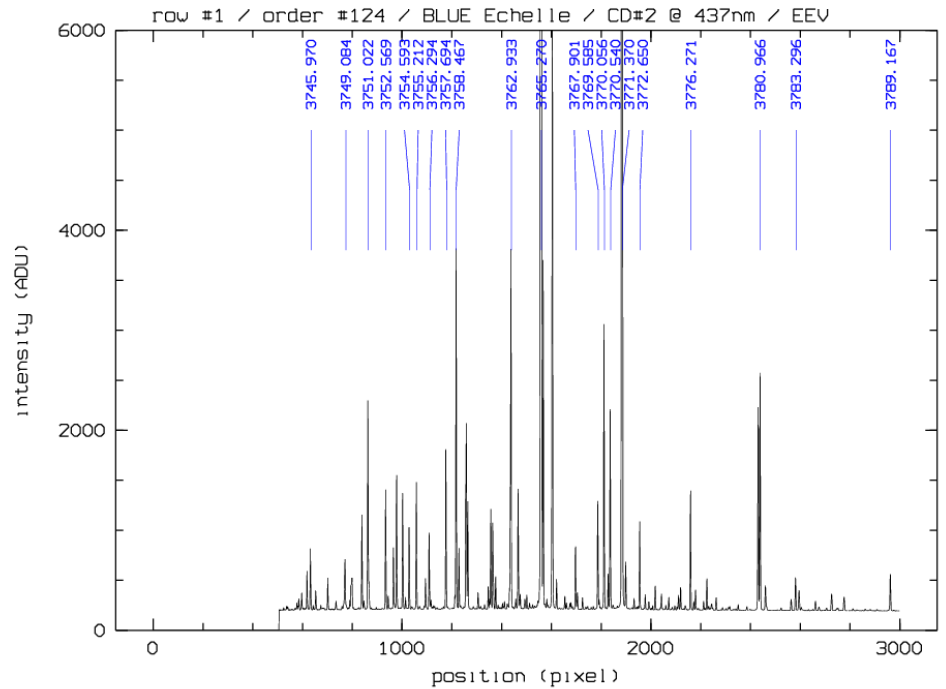
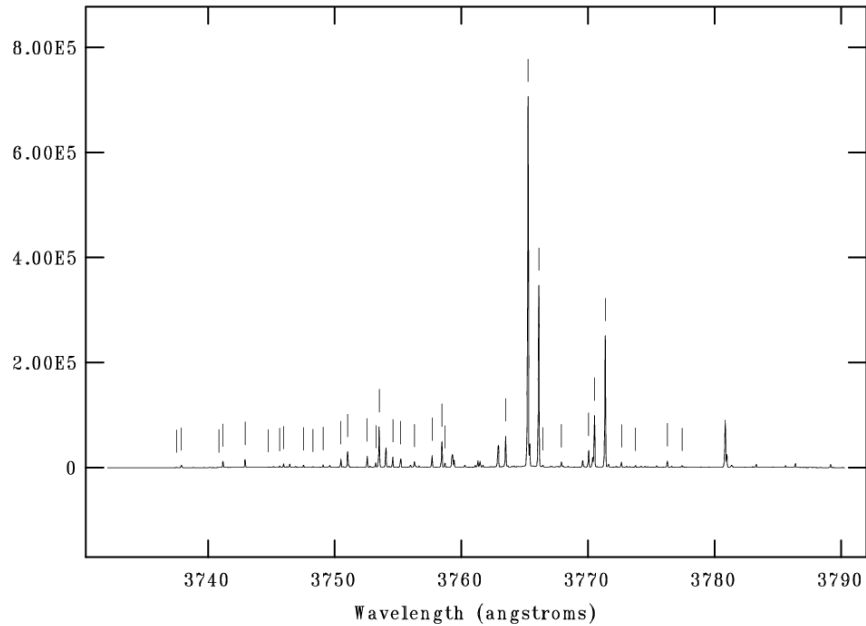


# WAVELENGTH CALIBRATION

UVES (real spectrum)

(from manual)

NOAO/IRAF V2.16.1 honza@crab Sun 16:13:05 05-Feb-2017  
Aperture 1, Image line 1, Order 124  
ecidentify thar1.ec: LAMP,WAVE



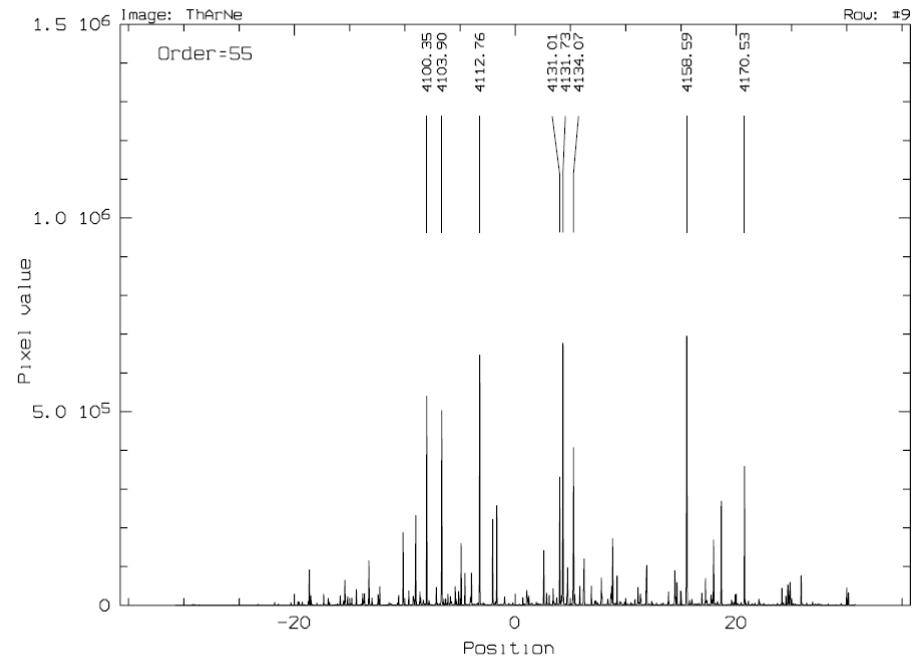
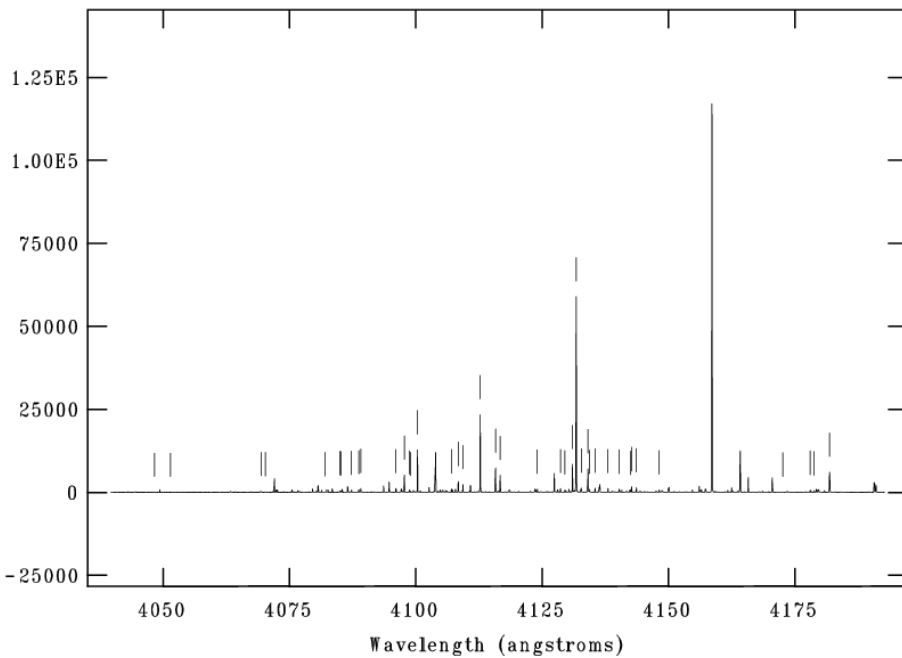


# WAVELENGTH CALIBRATION

FEROS (real spectrum)

(from manual)

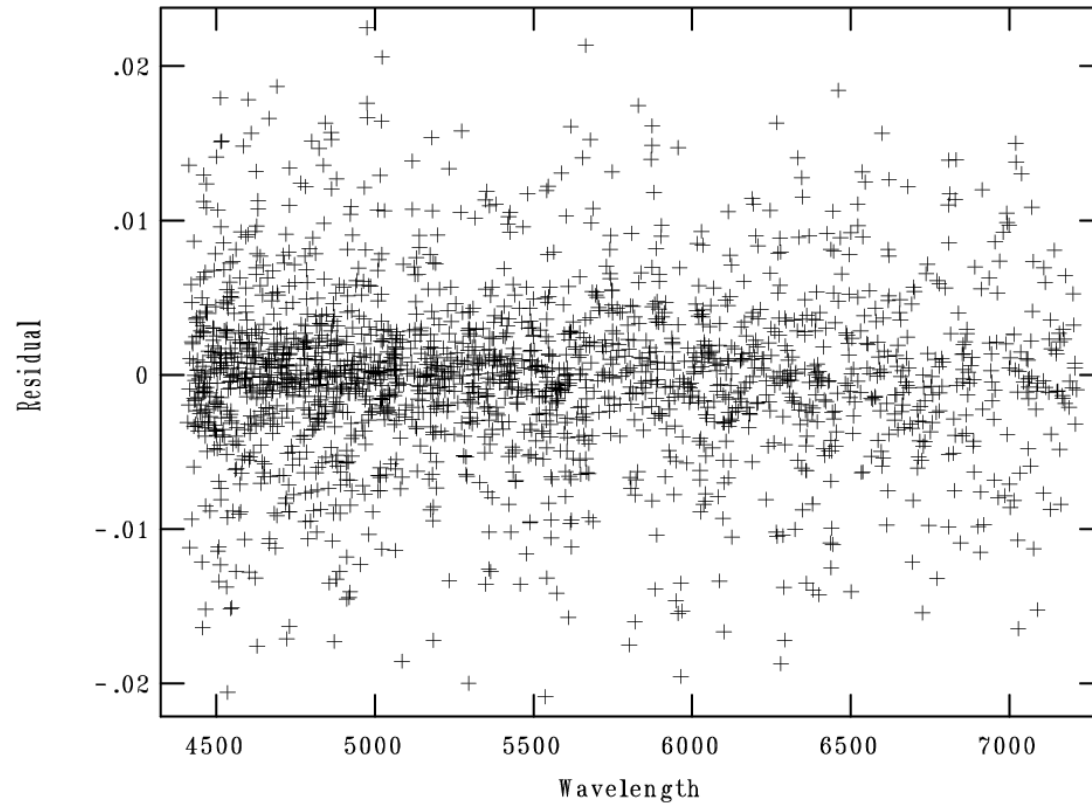
NOAO/IRAF V2.16.1 honza@crab Mon 09:42:12 06-Feb-2017  
Aperture 6, Image line 6, Order 55  
ecidentify ThArNe005.ec: BSCIR-005



# WAVELENGTH CALIBRATION

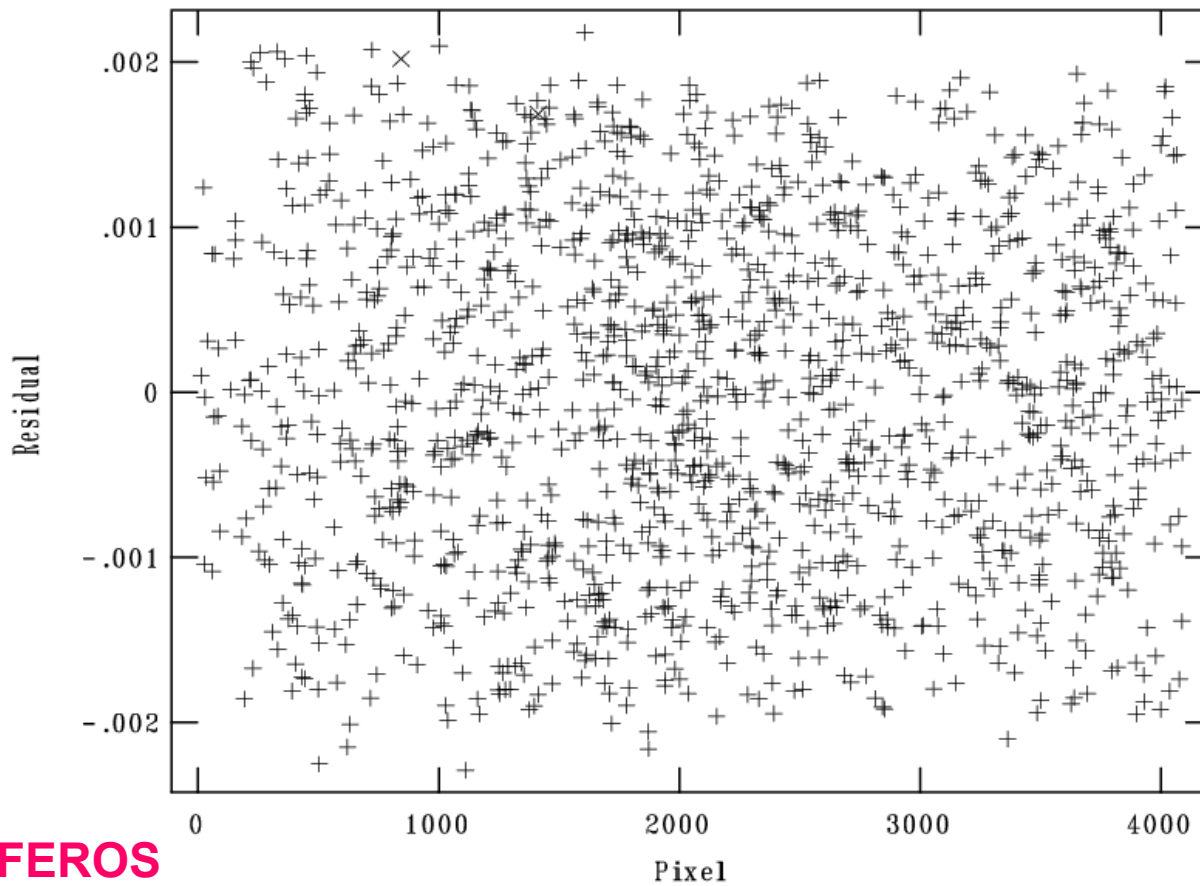
TUG

NOAO/IRAF V2.16.1 honza@crab Sun 16:01:47 05-Feb-2017  
Function=chebyshev, xorder=10, yorder=10, slope=1, offset=66, rms=0.005  
Echelle Dispersion Function Fitting



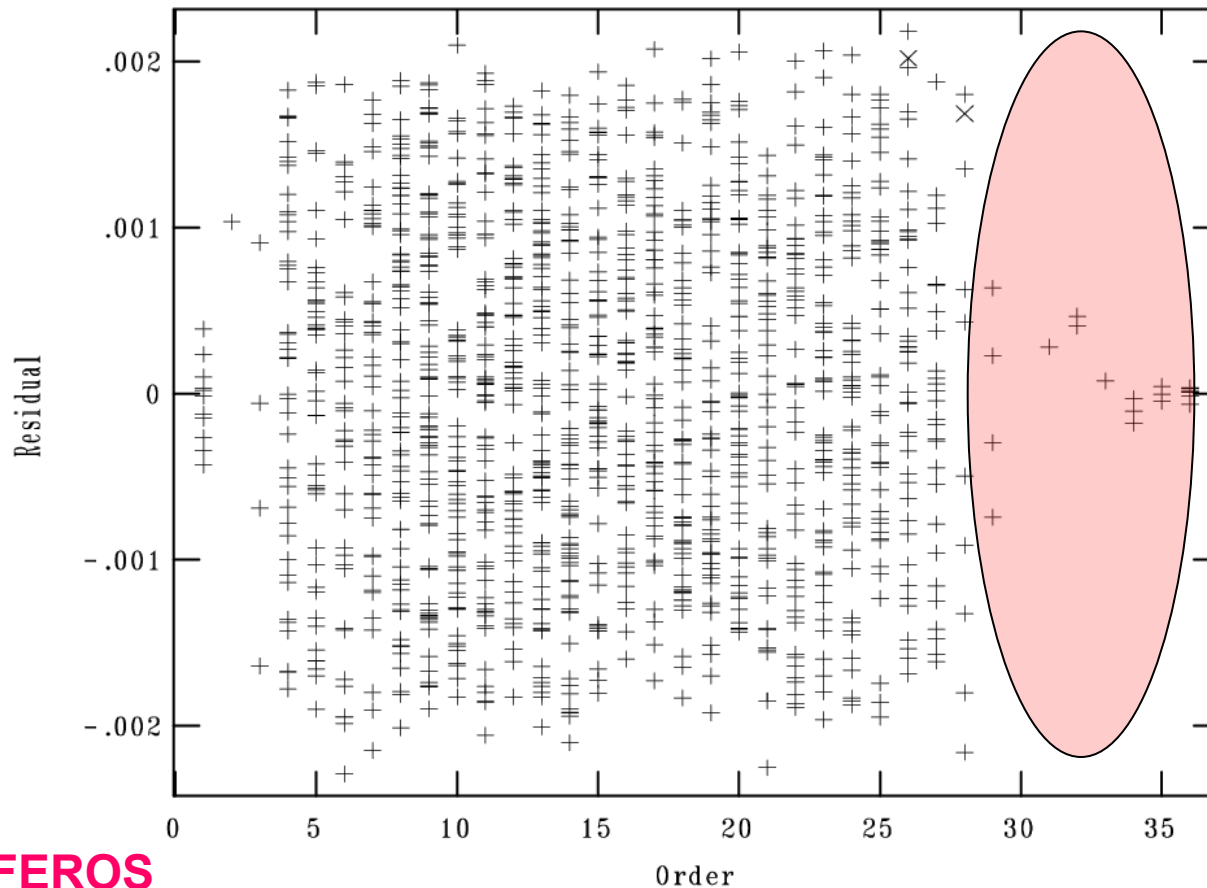
# WAVELENGTH CALIBRATION

NOAO/IRAF V2.16.1 honza@crab Mon 09:46:48 06-Feb-2017  
Function=chebyshev, xorder=10, yorder=10, slope=-1, offset=60, rms= 0.00  
Echelle Dispersion Function Fitting



# WAVELENGTH CALIBRATION

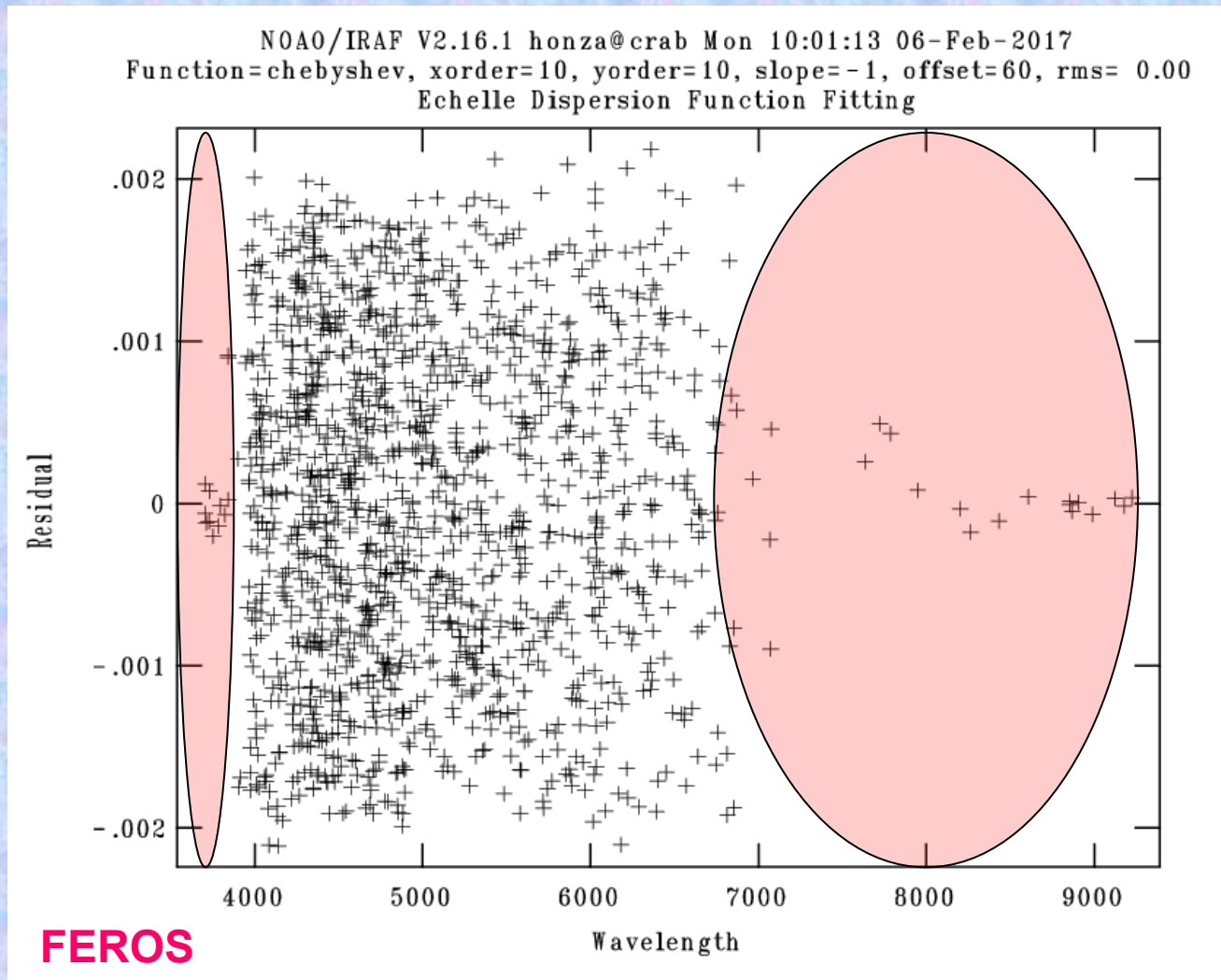
NOAO/IRAF V2.16.1 honza@crab Mon 09:50:07 06-Feb-2017  
Function=chebyshev, xorder=10, yorder=10, slope=-1, offset=60, rms= 0.00  
Echelle Dispersion Function Fitting



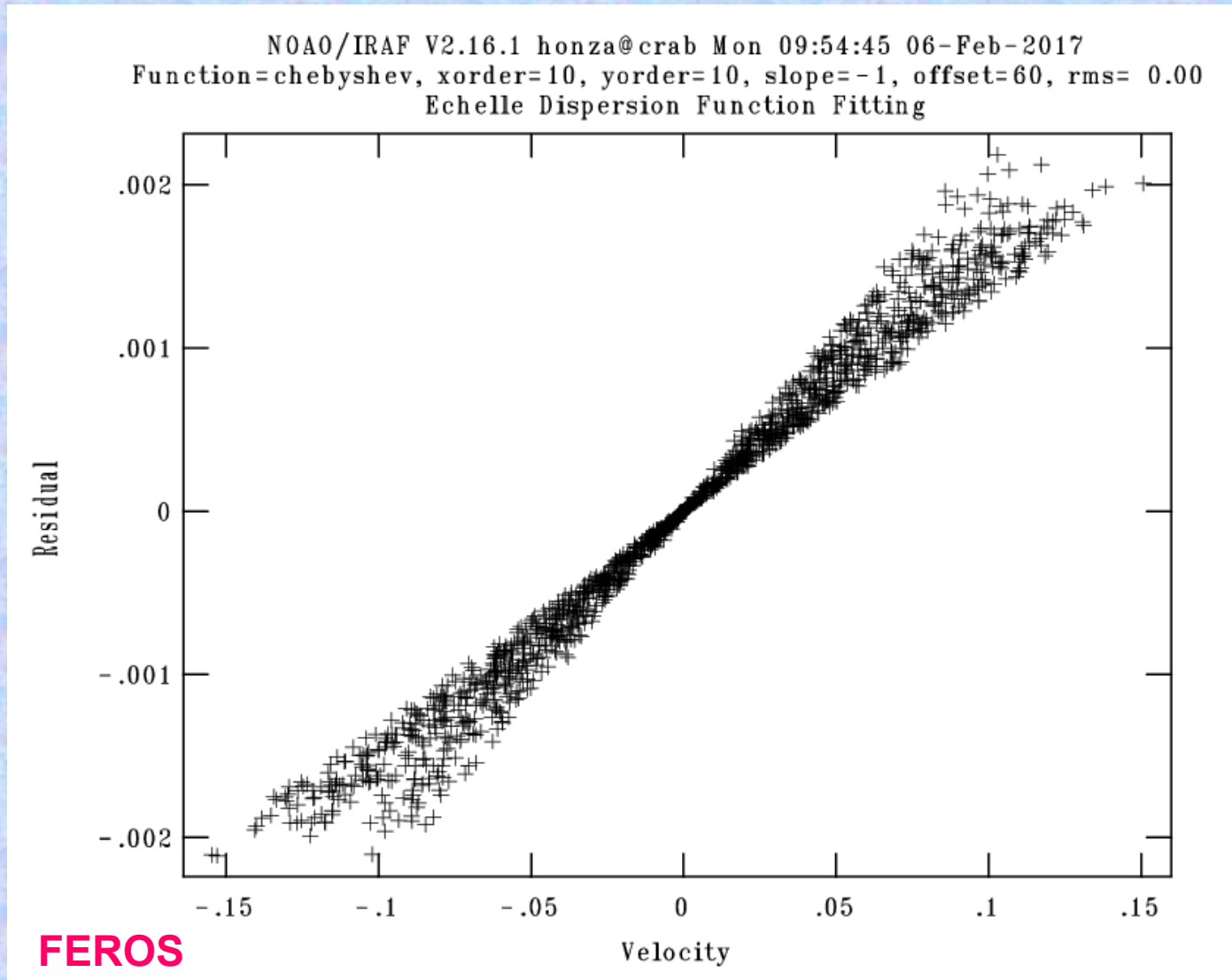
**FEROS**



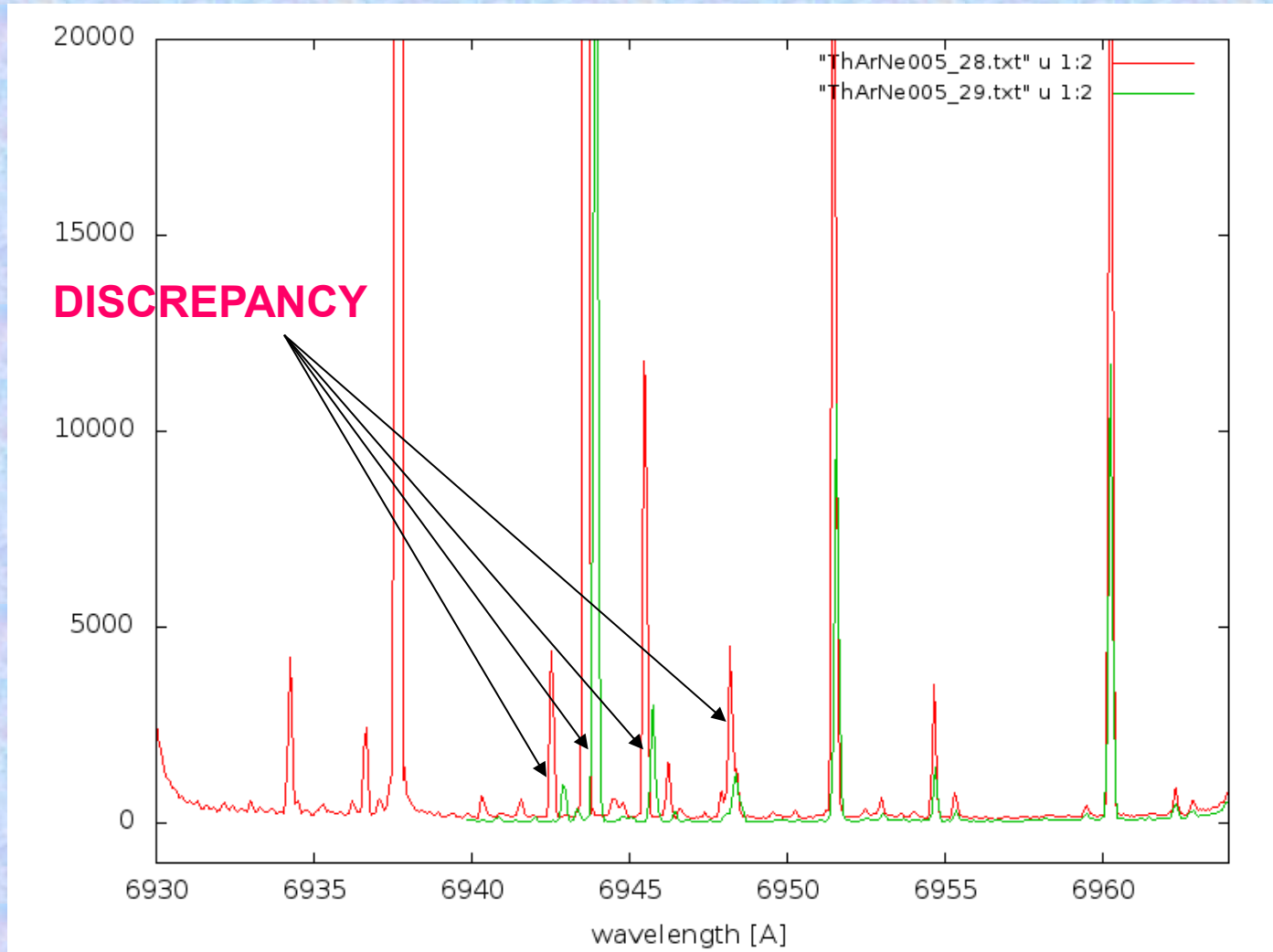
# WAVELENGTH CALIBRATION



# WAVELENGTH CALIBRATION



# WAVELENGTH CALIBRATION

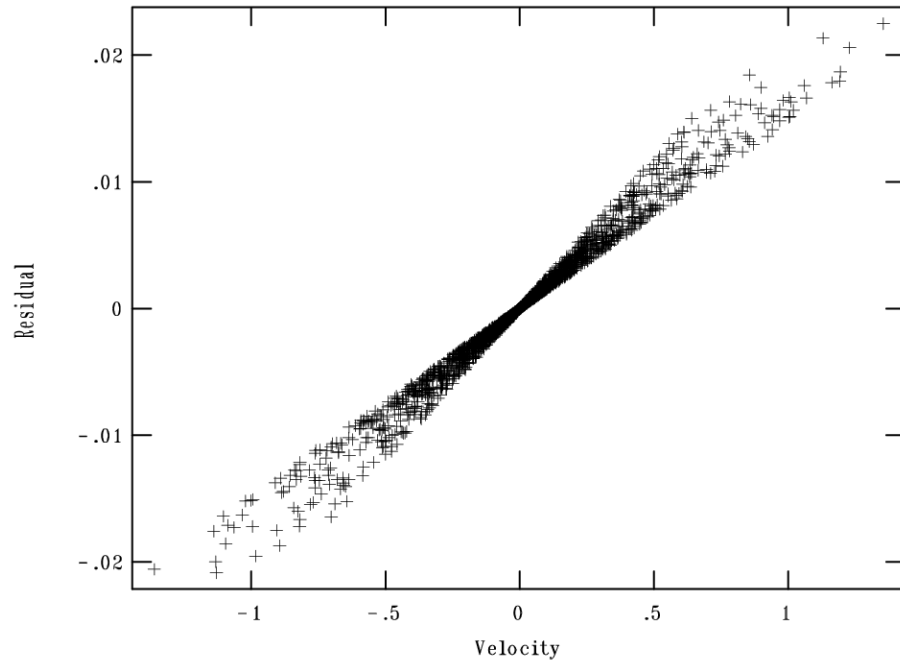


# WAVELENGTH CALIBRATION

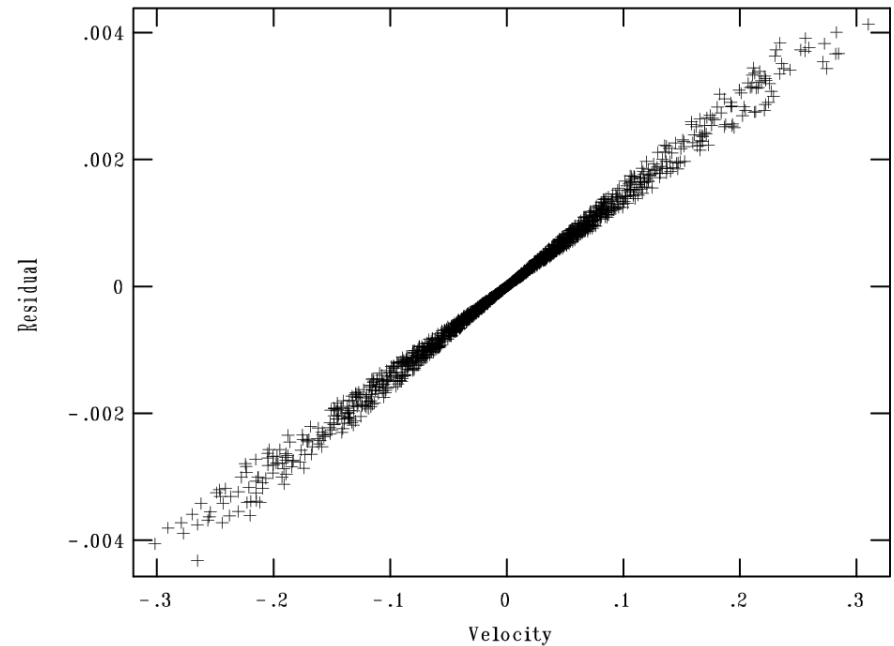
TUG (0.04 A/pix)

UVES (0.02 A/pix)

NOAO/IRAF V2.16.1 honza@crab Sun 16:03:41 05-Feb-2017  
Function=chebyshev, xorder=10, yorder=10, slope=1, offset=66, rms=0.005  
Echelle Dispersion Function Fitting

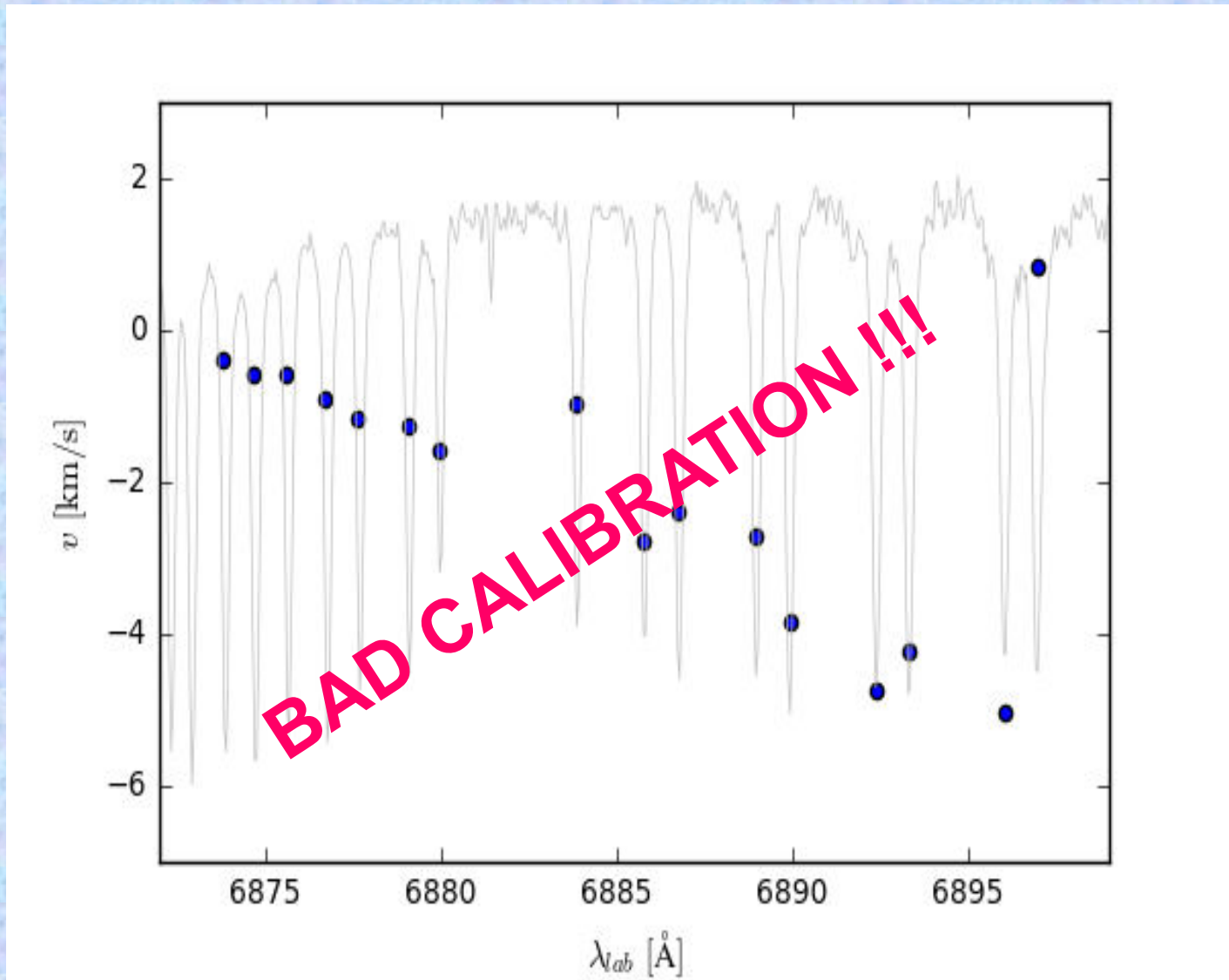


NOAO/IRAF V2.16.1 honza@crab Sun 16:08:00 05-Feb-2017  
Function=chebyshev, xorder=10, yorder=10, slope=-1, offset=125, rms=0.00  
Echelle Dispersion Function Fitting

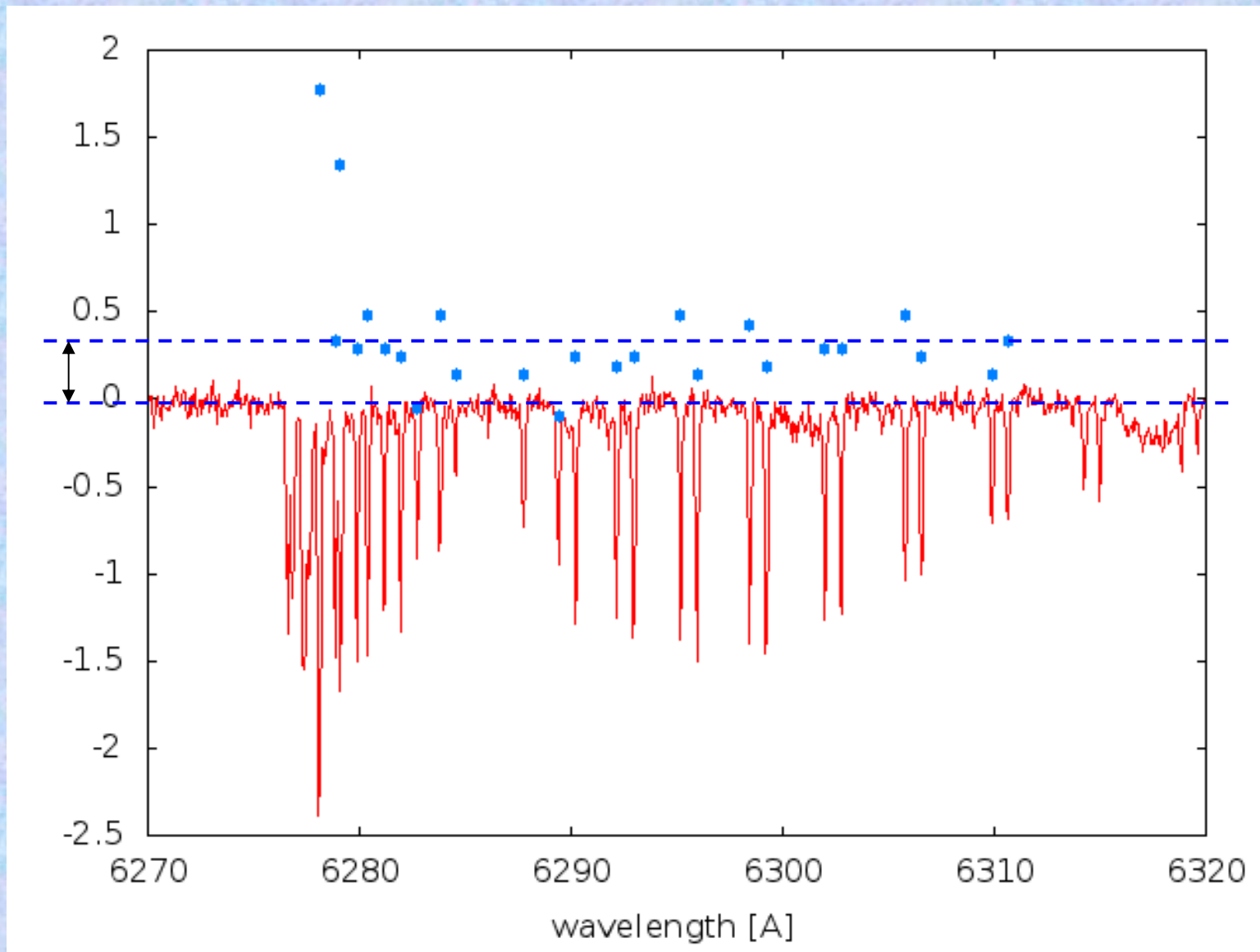




# TELLURIC LINE AS STANDARDS



# TELLURIC LINE AS STANDARDS



# HELIOCENTRIC / BARYCENTRIC VELOCITY CORRECTION

## Barycentric Velocity Correction (beta)

This online applet runs [barycorr](#) from [Wright & Eastman \(2014\)](#) which calculates the barycentric velocity correction for each UTC with a maximum error of 2.4 mm/s, compared to TEMPO2 (See Figures 2 and 3). Mouse over the inputs for an explanation and the required precision of inputs for desired precision of output. For 3 m/s precision, all optional fields can be ignored.

For m/s precision, one should calculate the barycentric correction throughout the exposure and perform a flux and barycentric correction weighted average. This error scales as the square of the exposure time.

There is a programmatic interface to this applet. [Here](#) is an example that recreates the values found in Table 2 (Tau Ceti with coordinates in the Hipparcos Epoch), multiplied by  $c$ . The optional parameters, if not specified, will default to the values displayed here. You may also set OBSNAME to an allowed string in [observatory.pro](#) and RAUNITS to "hours" to signify the input RA is in hours instead of its default of degrees.

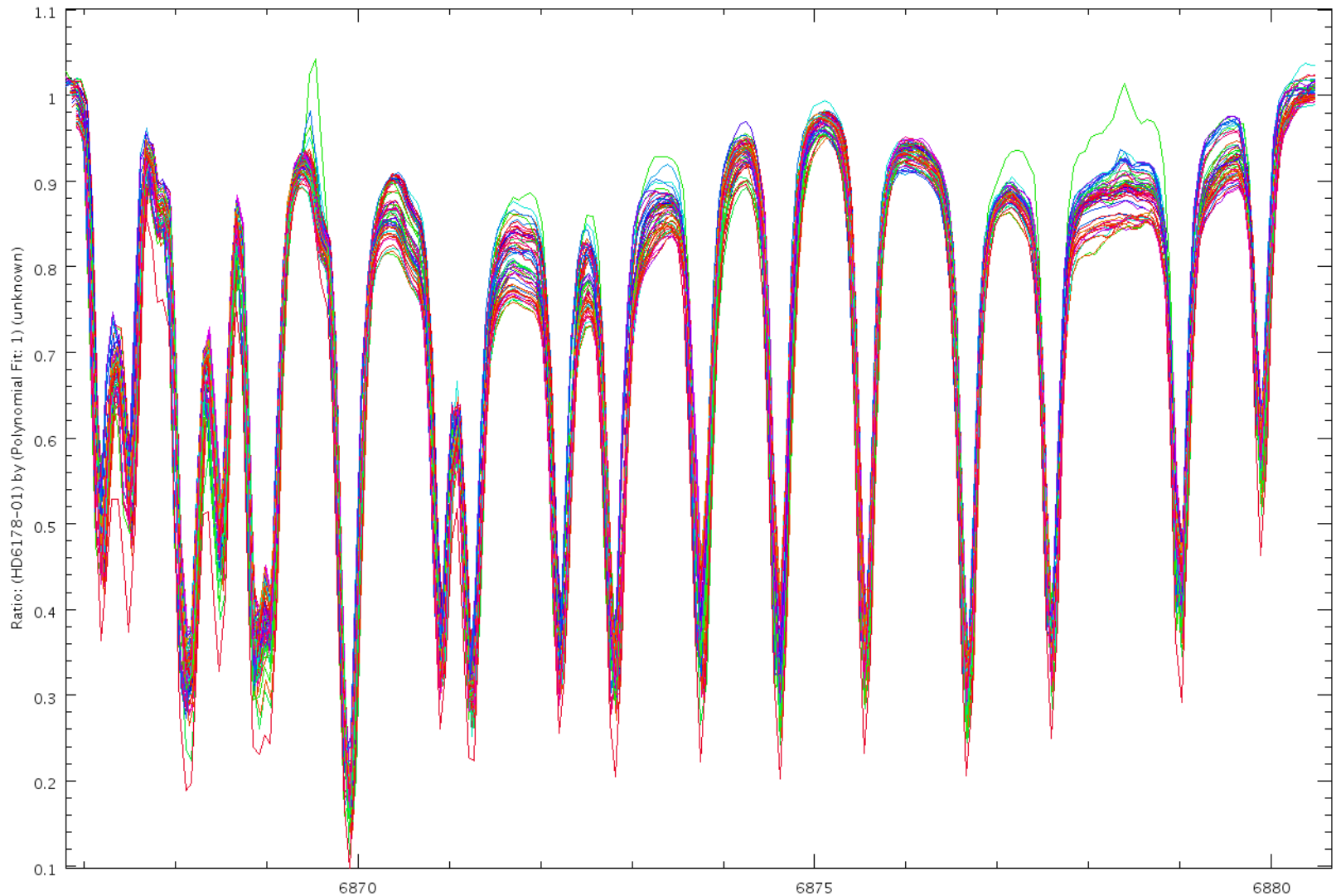
|  |   |                                       |                                    |
|--|---|---------------------------------------|------------------------------------|
| <a href="#">JD UTCs</a>                          | <a href="#">RA (J2000)</a>  | <a href="#">DEC (J2000)</a>           |                                    |
| <input type="text"/>                             | <input type="text"/> <input checked="" type="radio"/> HH MM SS.S<br><input type="radio"/> DDD.DDD | <input type="text"/> DD MM SS.S       |                                    |
|  | <a href="#">Earth-based observatory</a>   |                                       |                                    |
|  | <input type="text" value="Earth-based Observatory"/>  |                                       |                                    |
|  | -- or --  |                                       |                                    |
|  | <a href="#">Latitude (degrees)</a>  | <a href="#">Longitude (degrees E)</a> | <a href="#">Elevation (meters)</a> |
|  | <input type="text"/>  | <input type="text"/>                  | <input type="text"/>               |
|  | Only required for < 3 m/s precision   |                                       |                                    |
| <a href="#"><math>\mu_\alpha</math> (mas/yr)</a> | <a href="#"><math>\mu_\delta</math> (mas/yr)</a>  | <a href="#">Parallax (mas)</a>        | <a href="#">RV (m/s)</a>           |
| <input type="text" value="0.0"/>                 | <input type="text" value="0.0"/>  | <input type="text" value="0.0"/>      | <input type="text" value="0.0"/>   |
| <a href="#"><math>Z_{\text{meas}}</math></a>     | <a href="#">Epoch</a>   | <a href="#">Tbase (days)</a>          |                                    |
| <input type="text" value="0.0"/>                 | <input type="text" value="2451545.0"/>  | <input type="text" value="0.0"/>      |                                    |

Odeslat -- User inputs are NOT logged

If you have made use of this calculator (or the [source code](#)) in a scientific paper, please cite [our paper](#), which contains a more thorough explanation of the various corrections involved in this calculation.

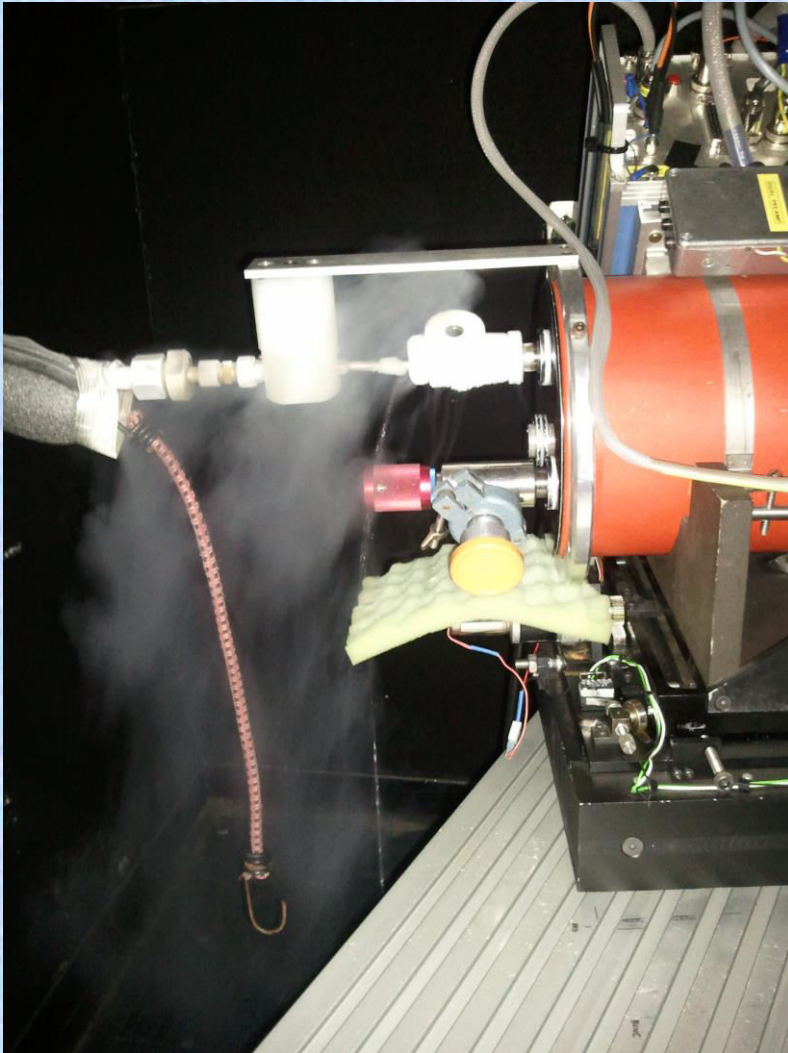
Copyright © [Jason Eastman](#) (jason.eastman@cfa.harvard.edu) All Rights Reserved. Questions, comments, or bug reports welcome.  
Last revised: Apr 28, 2016 [jde/cfa]

# SPECTROGRAPH STABILITY





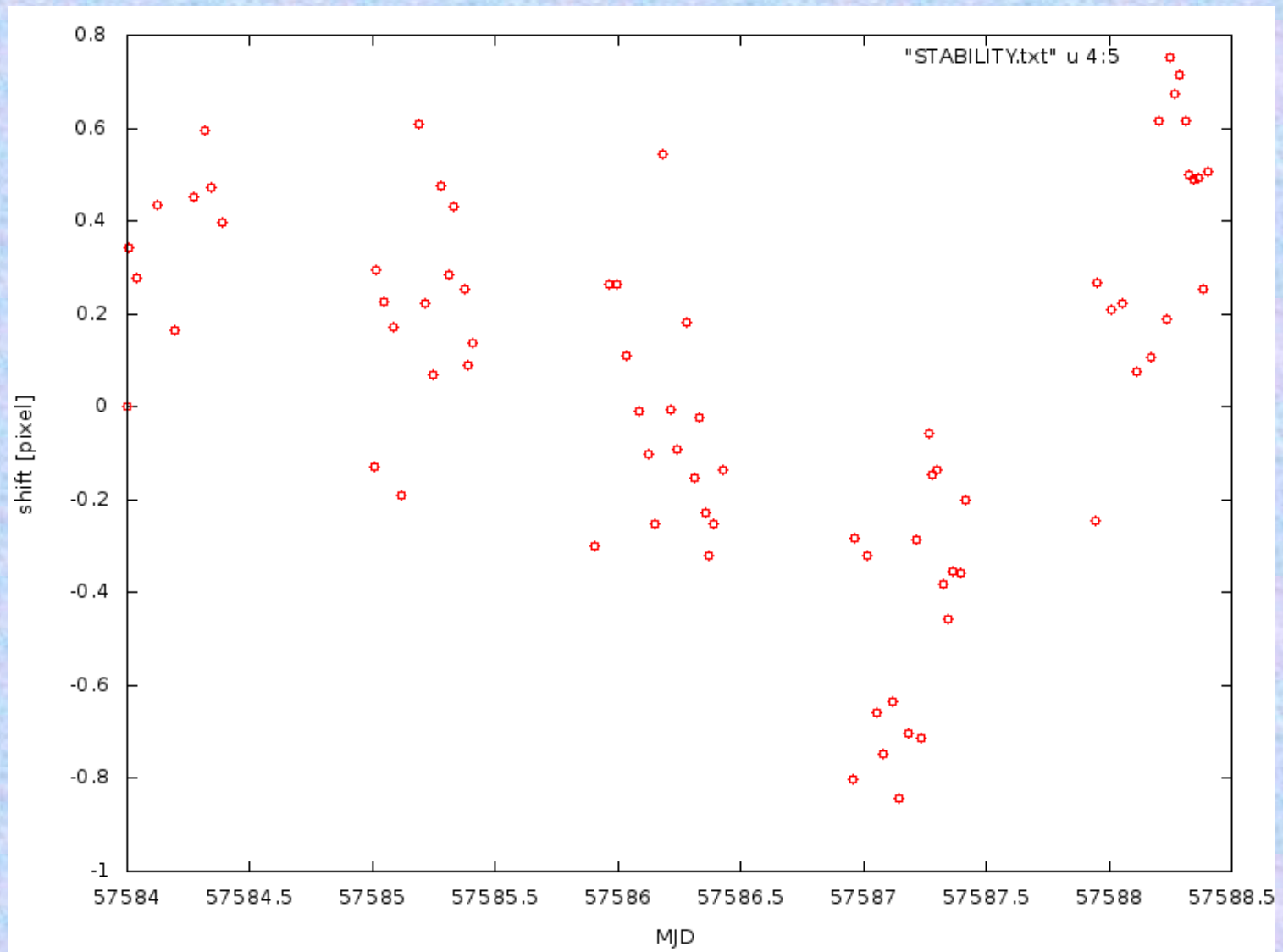
# SPECTROGRAPH STABILITY



VERY STABLE  
TEMPERATURE

IF NOT ....

# SPECTROGRAPH STABILITY



# HARPS Radial Velocities

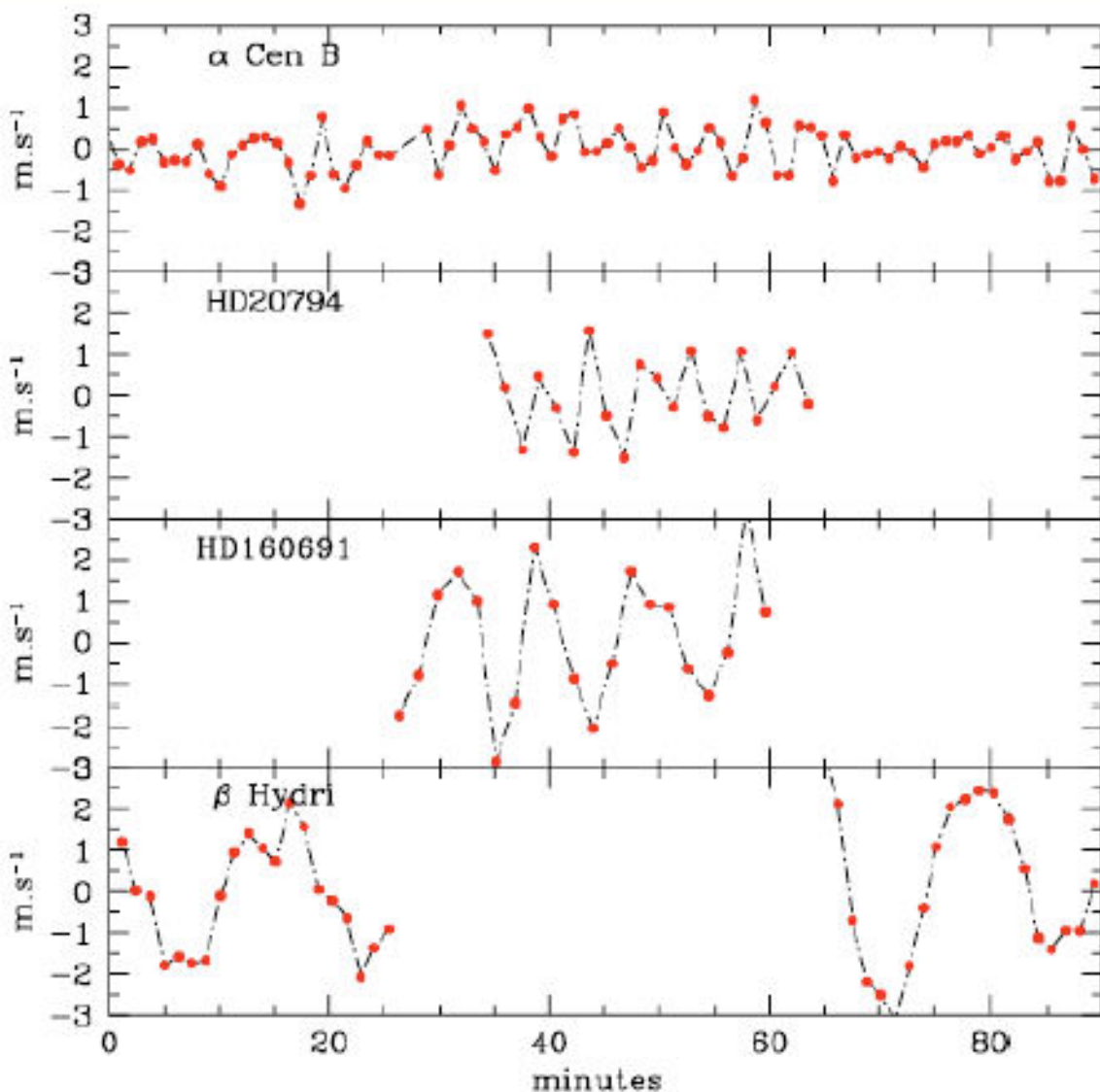
Question: What is wrong with this argument?

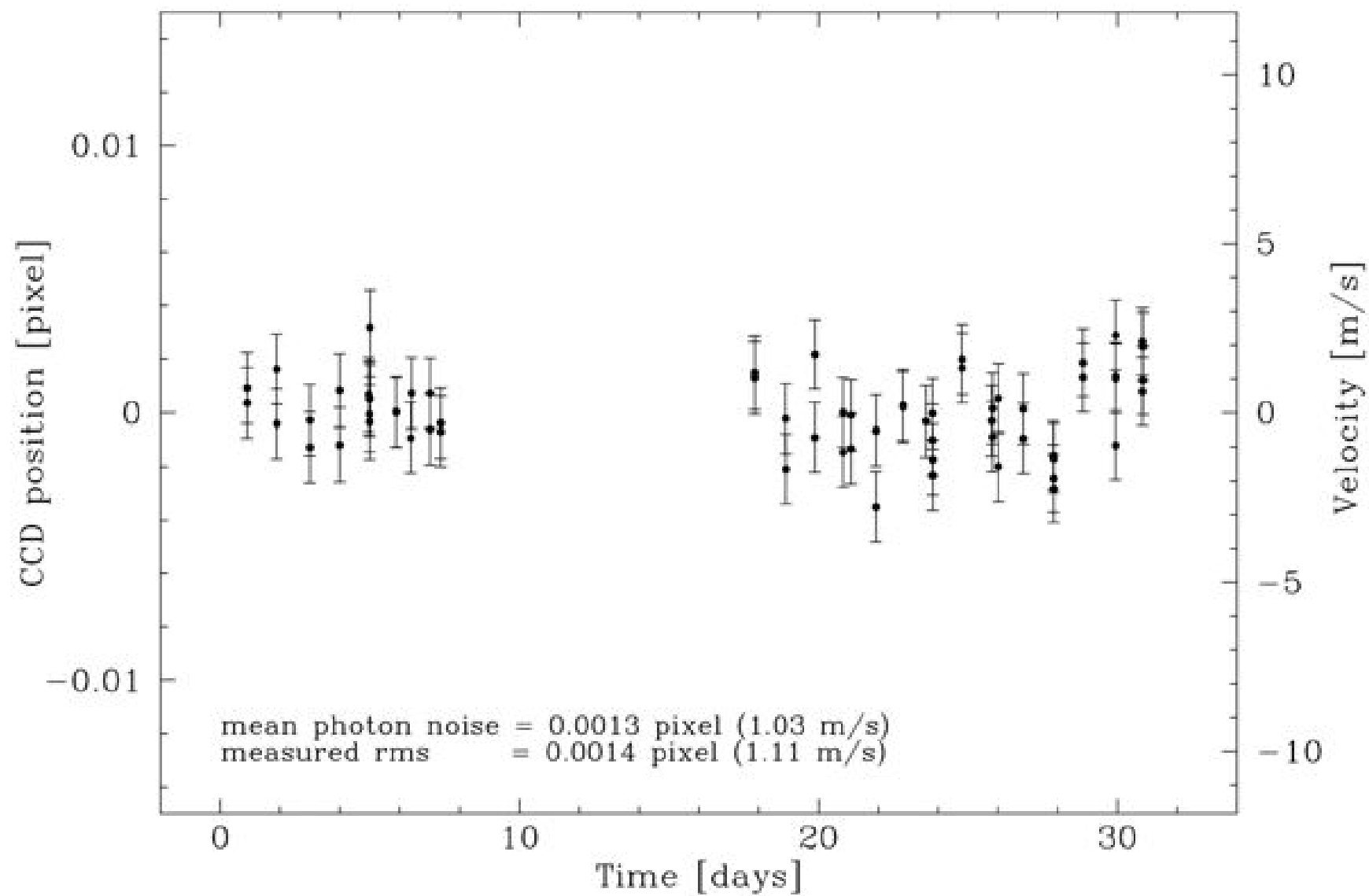
$$\Delta\lambda/\lambda = 10^{-5}$$

$$\Delta\lambda/\lambda = v_{min}/c$$

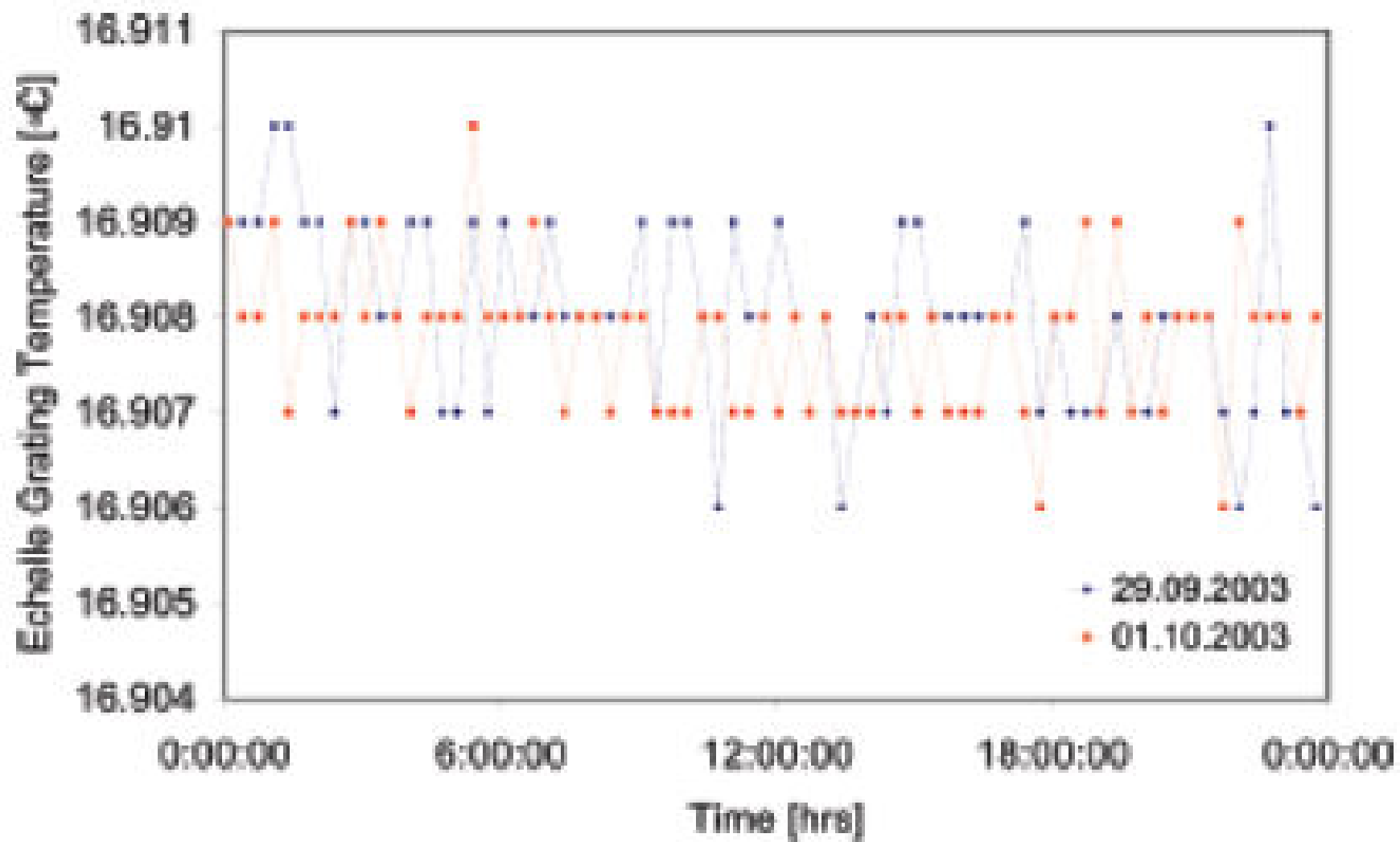
Therefore,

$$v_{min} = 3 \times 10^3 \text{ m/s}$$



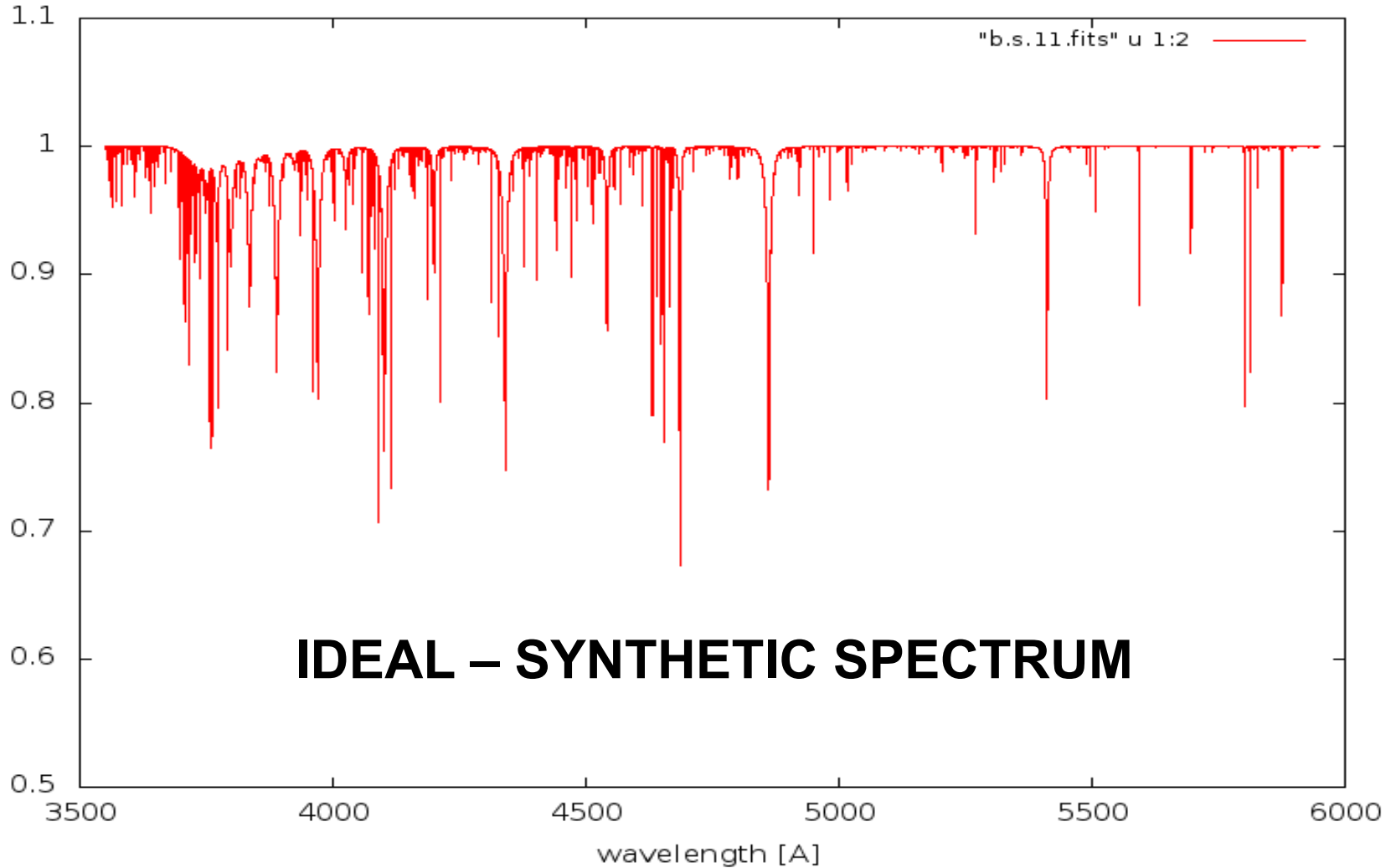




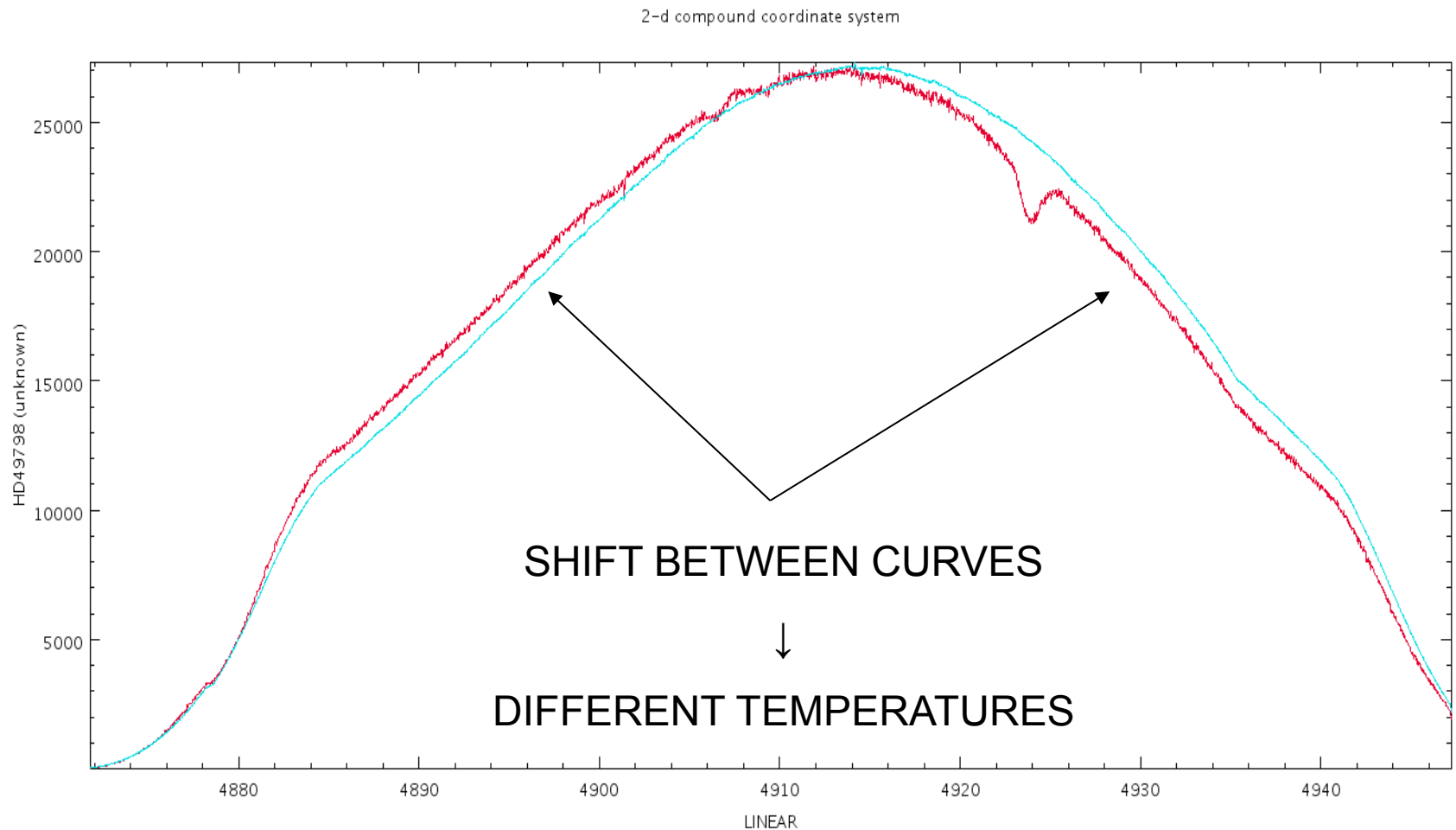


| <b>planet</b>            | <b>planet type</b>        | <b>major axis (AU)</b> | <b>period</b>   | <b>radial velocity (m/s)</b> |
|--------------------------|---------------------------|------------------------|-----------------|------------------------------|
| <b>51 Pegasi b</b>       | <b>hot Jupiter</b>        | <b>0.05</b>            | <b>4.23 d</b>   | <b>55.9</b>                  |
| <b>55 Cancri d</b>       | <b>gas giant</b>          | <b>5.77</b>            | <b>14.29 y</b>  | <b>45.2</b>                  |
| <b>Jupiter</b>           | <b>gas giant</b>          | <b>5.20</b>            | <b>11.86 y</b>  | <b>12.4</b>                  |
| <b>Gliese 581c</b>       | <b>super-Earth</b>        | <b>0.07</b>            | <b>12.92 d</b>  | <b>3.18</b>                  |
| <b>Saturn</b>            | <b>gas giant</b>          | <b>9.58</b>            | <b>29.46 y</b>  | <b>2.75</b>                  |
| <b>Alpha Centauri Bb</b> | <b>terrestrial planet</b> | <b>0.04</b>            | <b>3.23 d</b>   | <b>0.510</b>                 |
| <b>Neptun</b>            | <b>gas giant</b>          | <b>30.10</b>           | <b>164.79 y</b> | <b>0.281</b>                 |
| <b>Earth</b>             | <b>habitable planet</b>   | <b>1.00</b>            | <b>365.26 d</b> | <b>0.089</b>                 |
| <b>Pluto</b>             | <b>dwarf planet</b>       | <b>39.26</b>           | <b>246.04 y</b> | <b>0.00003</b>               |

# CONTINUUM NORMALISATION



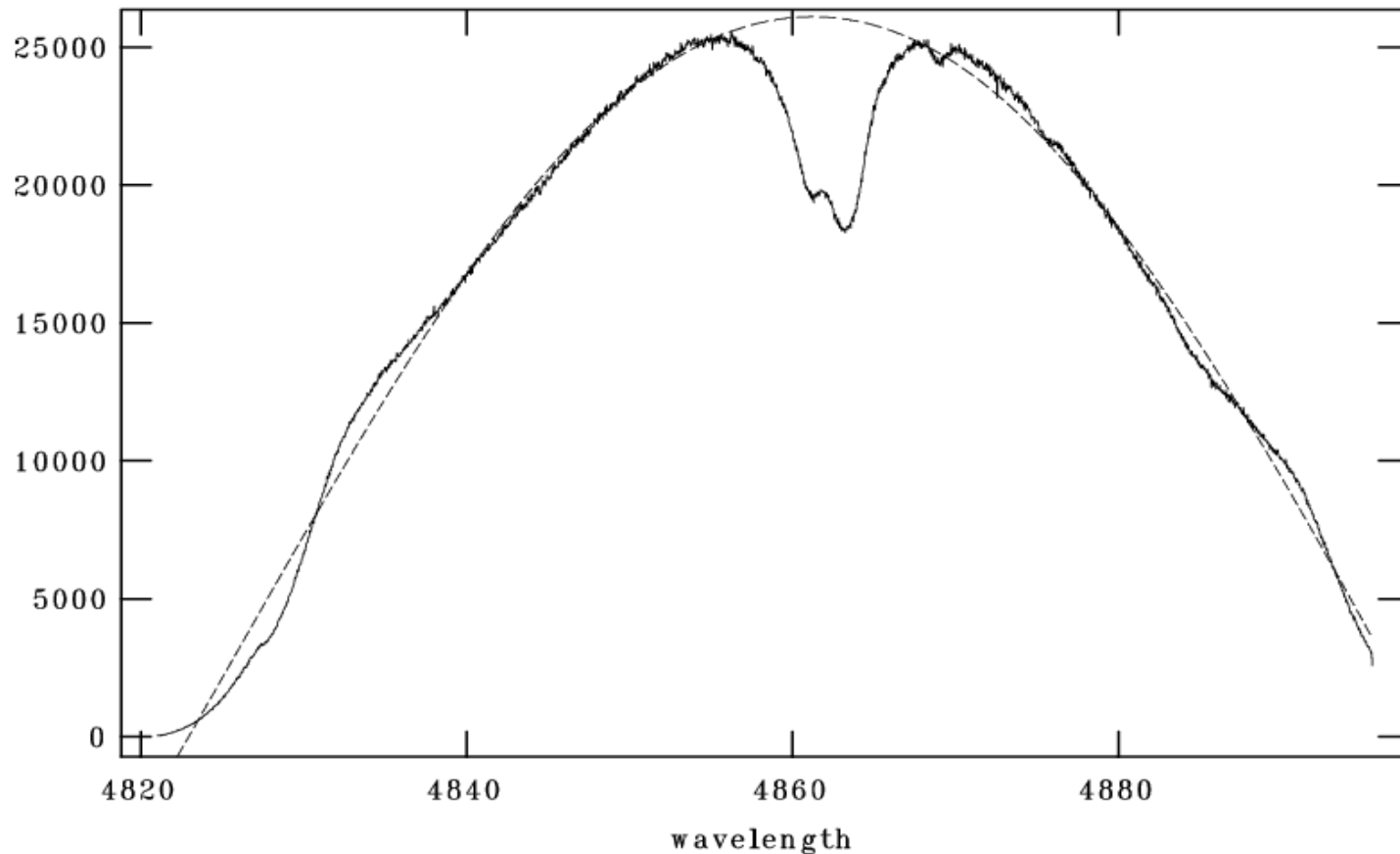
# CONTINUUM NORMALISATION





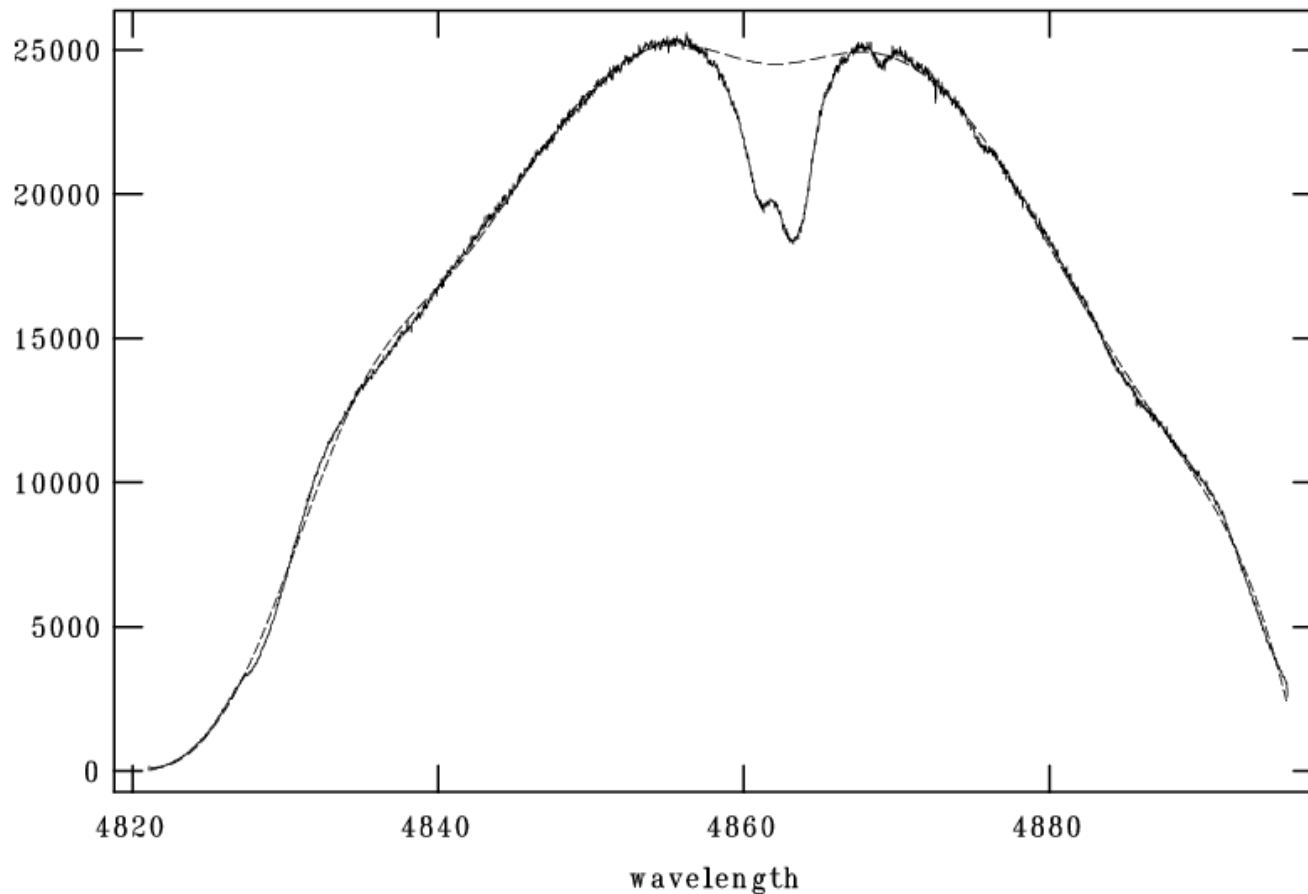
# CONTINUUM NORMALISATION

NOAO/IRAF V2.16.1 honza@crab Mon 14:55:11 06-Feb-2017  
func=spline3, order=3, low\_rej=3, high\_rej=0, niterate=10, grow=1  
total=3000, sample=3000, rejected=321, deleted=0, RMS= 618.9  
HD49798\_29.fits, [1,1]  
HD49798

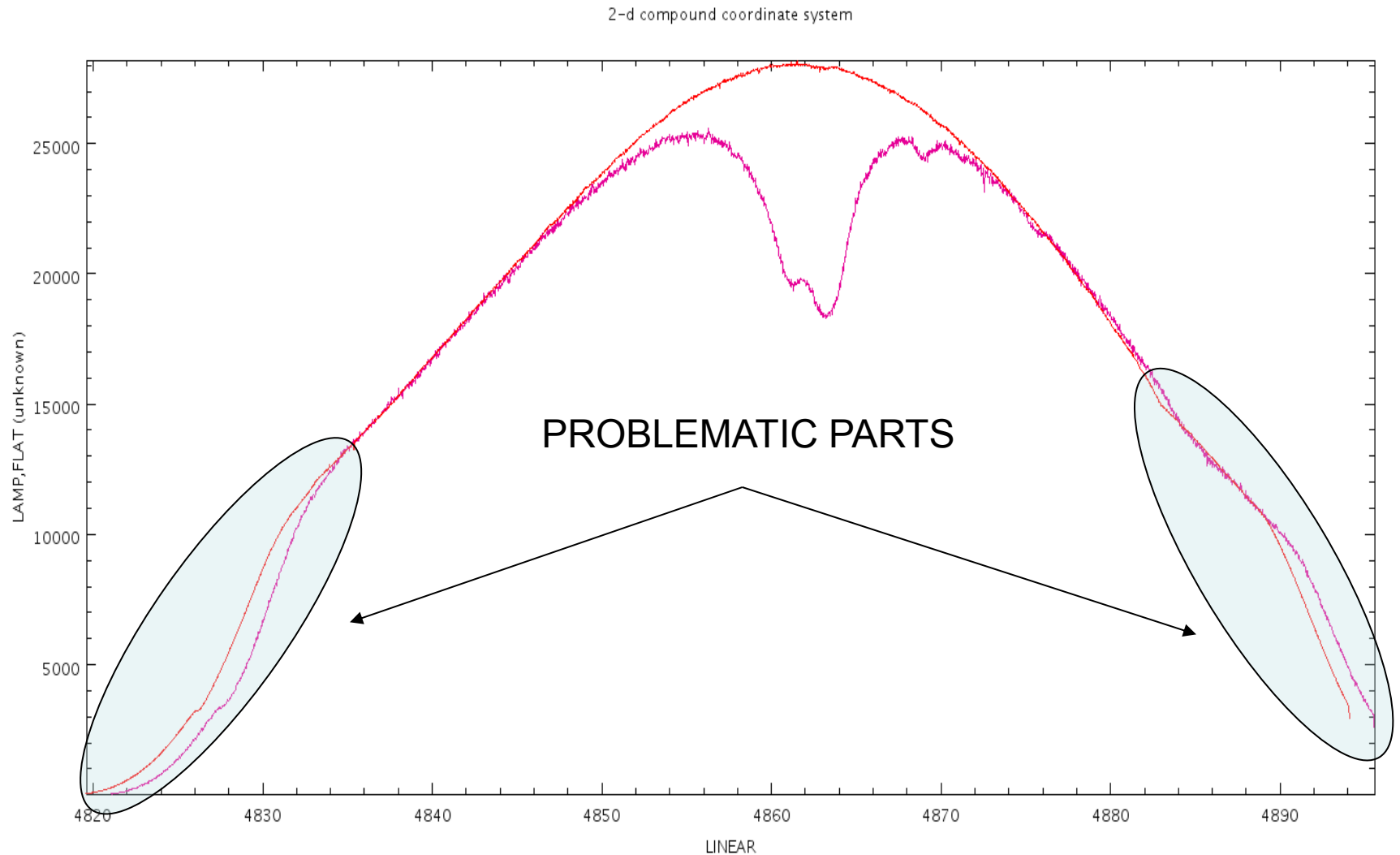


# CONTINUUM NORMALISATION

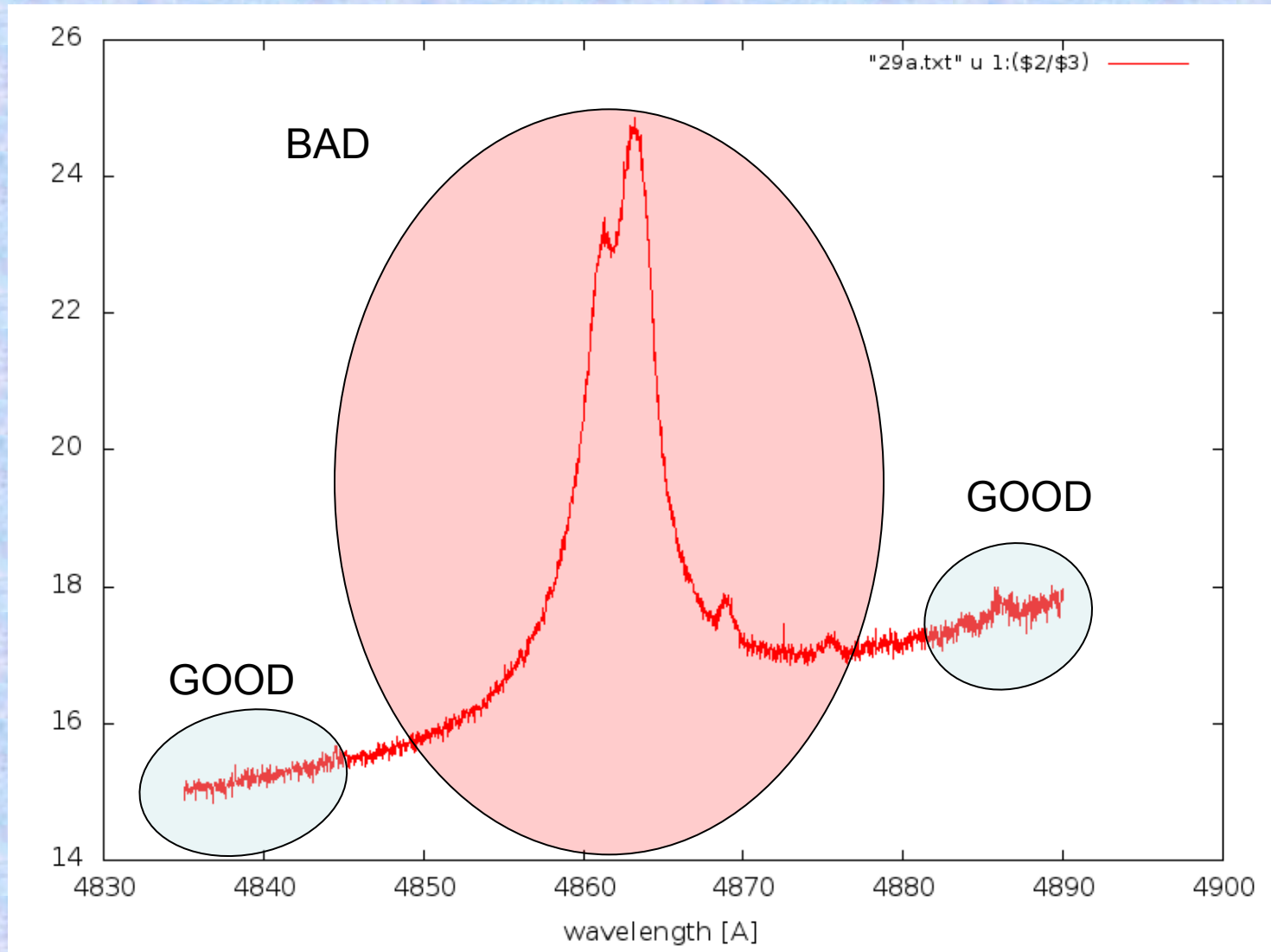
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NOAO/IRAF V2.16.1 honza@crab Mon 14:57:10 06-Feb-2017  
func=spline3, order=11, low_rej=3, high_rej=0, niterate=10, grow=1  
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HD49798_29.fits, [1,1]  
HD49798
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# CONTINUUM NORMALISATION

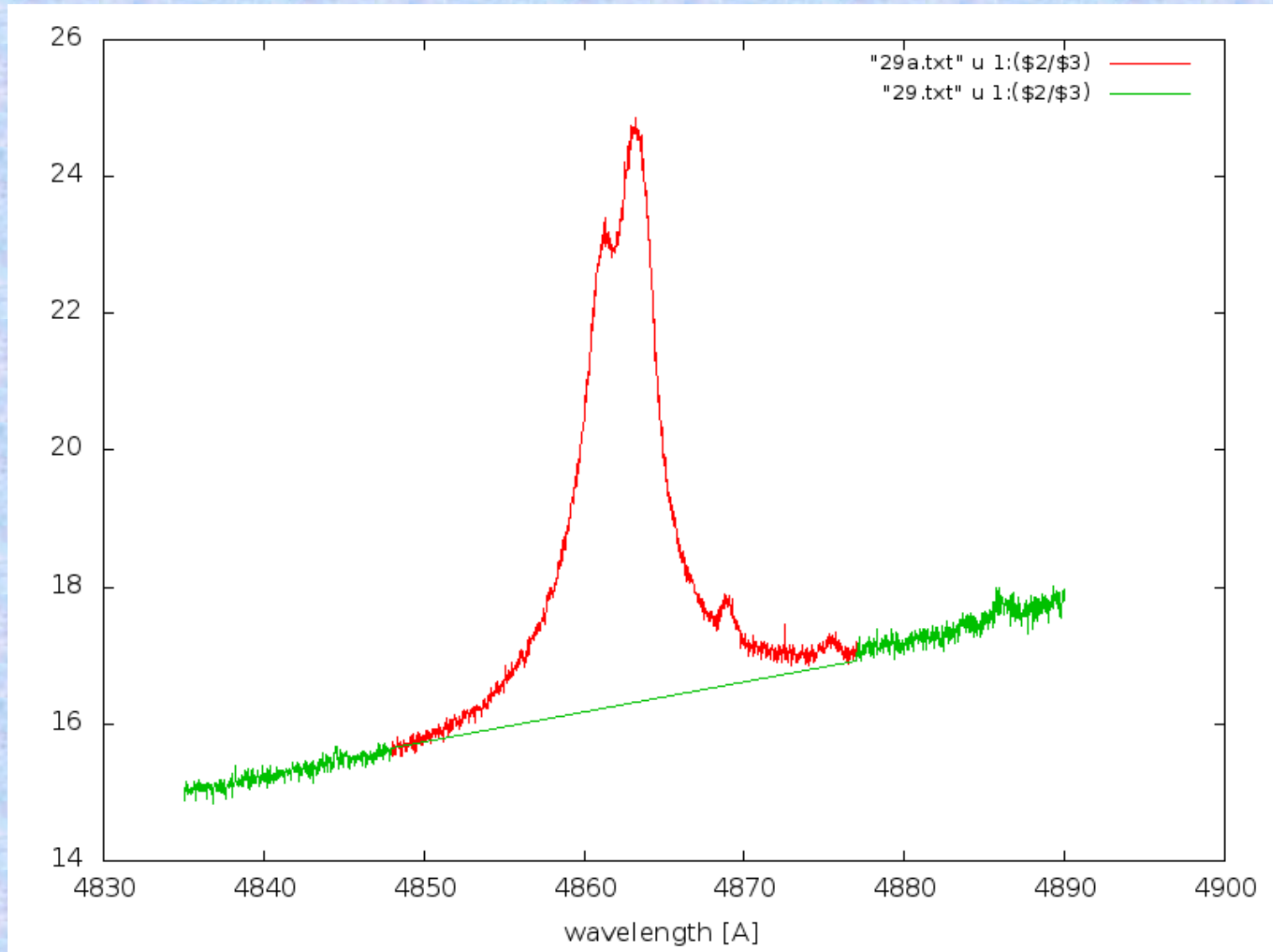


# CONTINUUM NORMALISATION

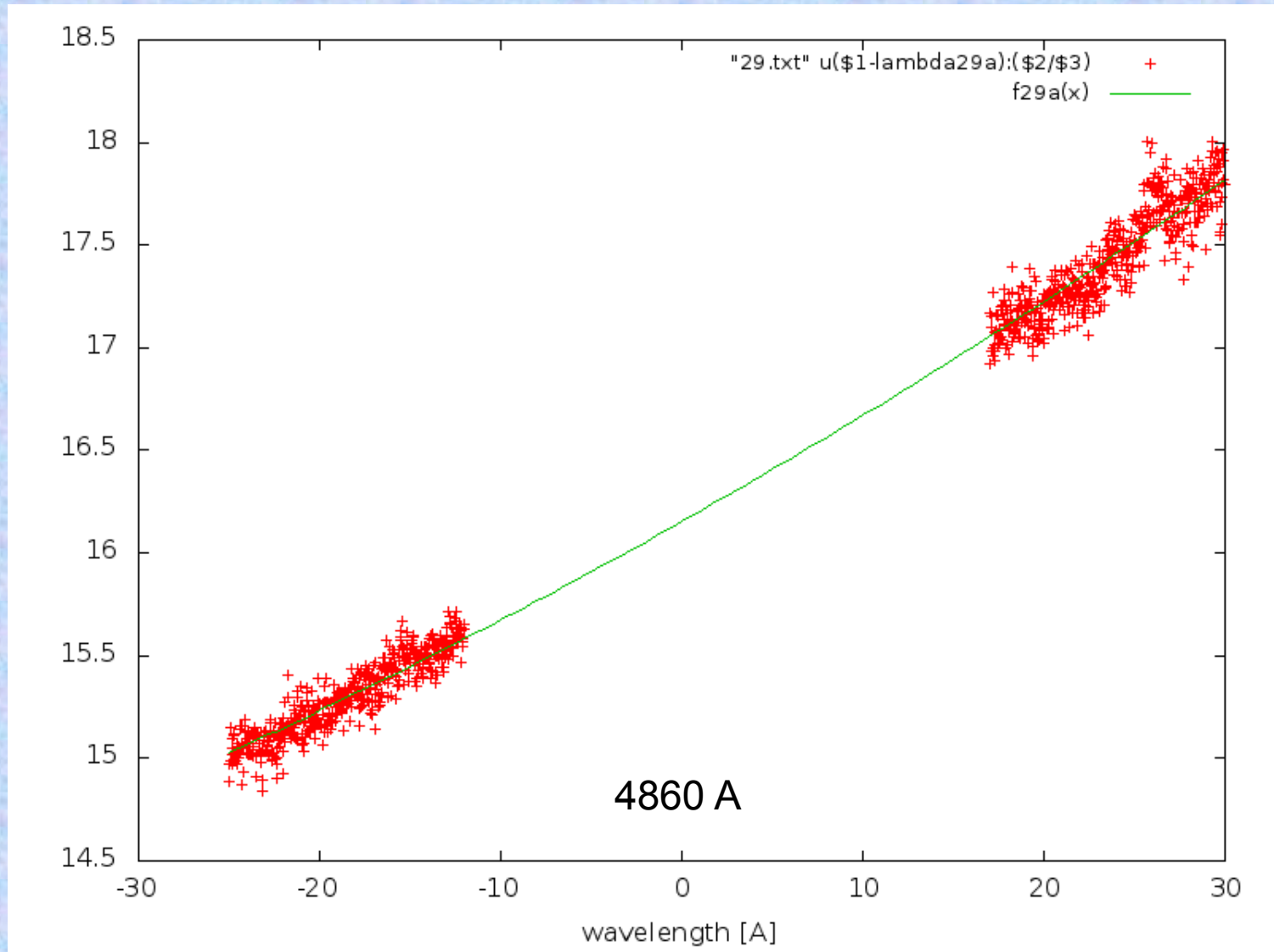




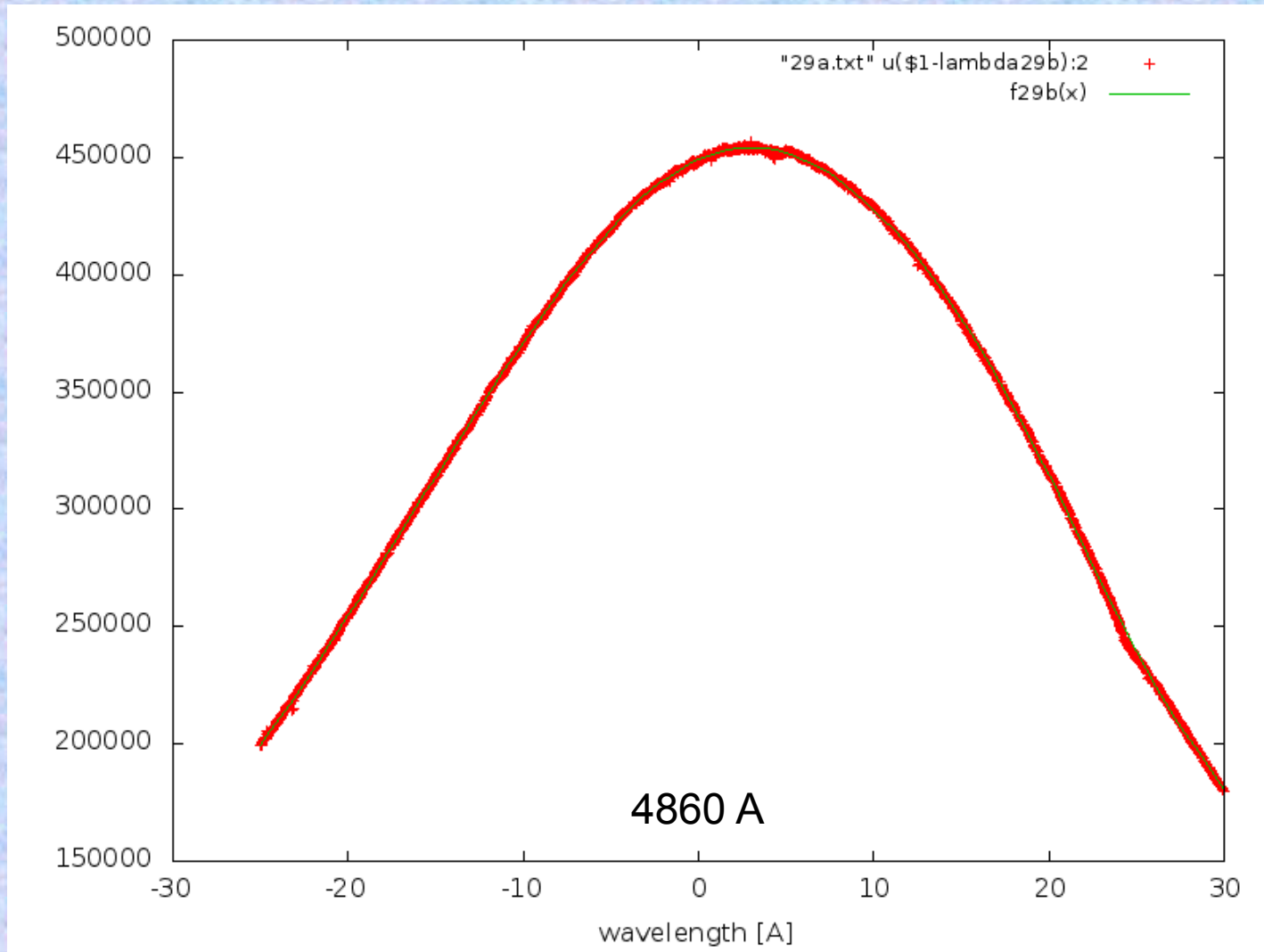
# CONTINUUM NORMALISATION



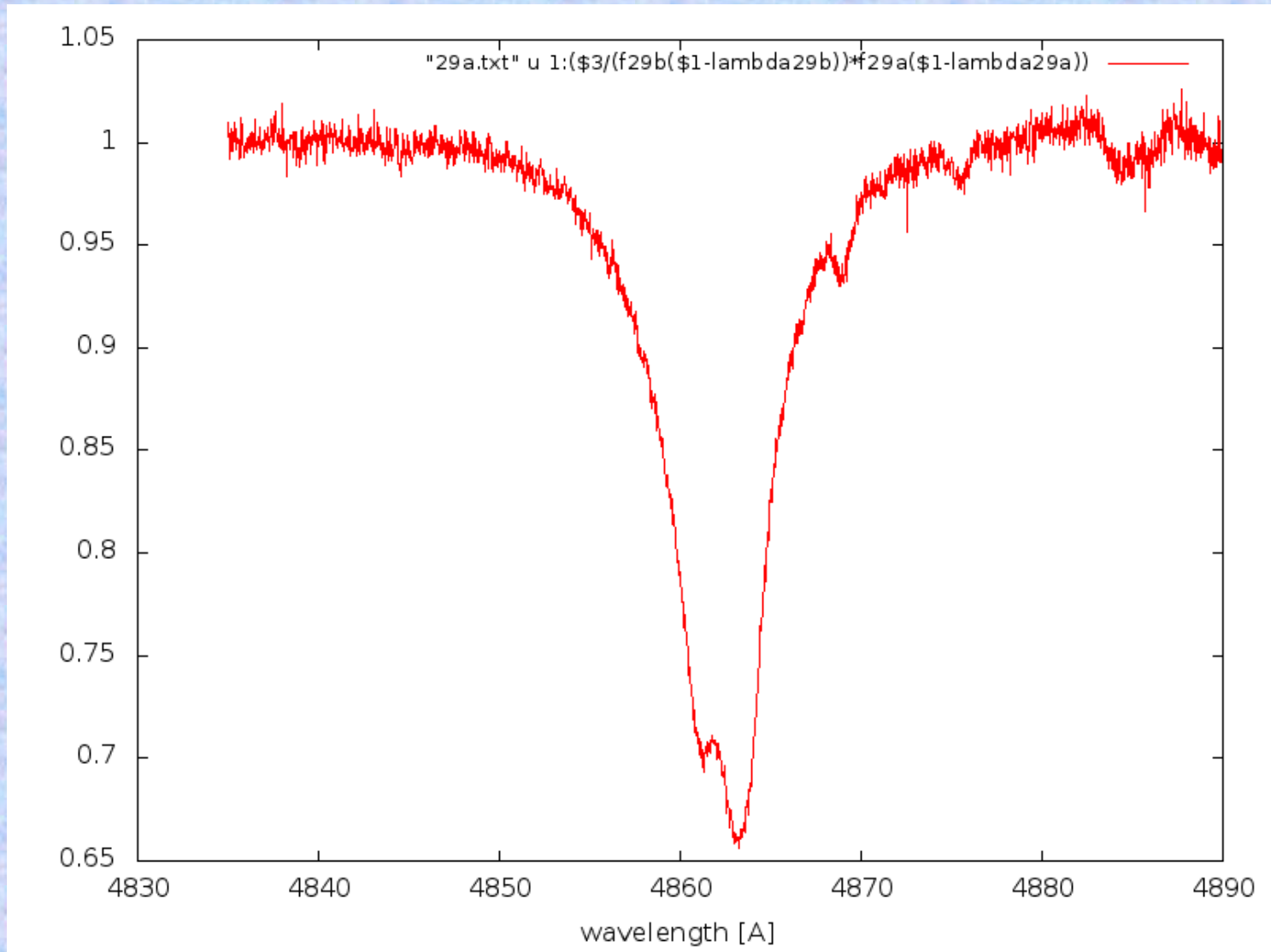
# CONTINUUM NORMALISATION



# CONTINUUM NORMALISATION

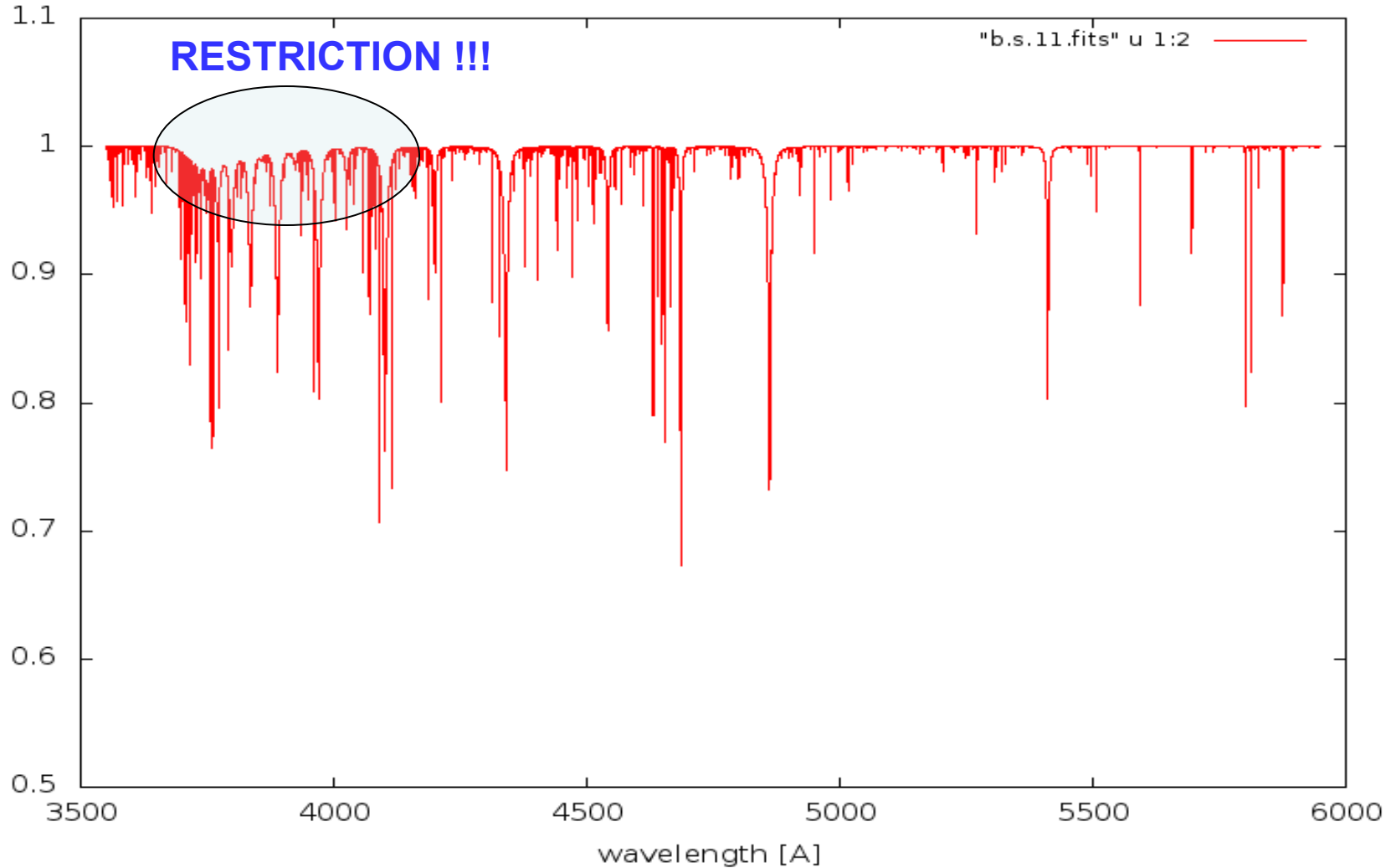


# CONTINUUM NORMALISATION





# CONTINUUM NORMALISATION



THANK YOU FOR  
YOUR ATTENTION !!!

